

**THE RECORDING AND ARCHAEOLOGICAL
POTENTIAL OF TOOL MARKS ON
PREHISTORIC WORKED WOOD**

**with special reference to
Oakbank Crannog, Loch Tay, Scotland.**

In two volumes

Volume 1

The Text

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Declaration

I declare that this thesis has been composed by me and that the work contained within it has been conducted by me.

Abstract

Well-preserved waterlogged timbers are increasingly being found as more wetland and submerged archaeological sites are being investigated. Such timbers can often preserve a record of the tools used in their working and it is this detail that is at the core of the current study.

When a tool is used to work wood the details of its blade edge can be very well preserved on the timber's surface. Points of damage on a blade, possibly a break or bend in the edge, can be registered on the wood surface as either a ridge or a groove running down the long axis of the facet produced. The sequence of ridges or grooves created by a blade can act like a signature for the use of that particular tool. When the same sequence of ridges and grooves are found on facets from different timbers those timbers can be associated through the single tool used in their working. Associations produced in this manner represent manufacture that is probably no more than a few hours apart. Crucially this is directly related to the working of the timbers and is independent of the evidence of association that might be demonstrated through other techniques, such as dendrochronology. This thesis explores the archaeological uses of such information on waterlogged settlement sites with a number of constructional phases.

Wooden material from the Late Bronze/Early Iron Age site of Oakbank Crannog, Loch Tay, Perthshire, Scotland, provides the data for this investigation. Crannogs are artificial islands found in both Scottish and Irish lochs. Many crannog sites are now completely submerged and Oakbank crannog represents the only example in Scotland to be excavated underwater using diving equipment.

The thesis covers aspects of data retrieval, examination and interpretation. The submerged setting of the site has made necessary the development of data retrieval methods that can be used underwater. The use of dental moulding techniques has enabled the fine detail of toolmark signatures to be recorded in-situ. Data examination has primarily relied on the visual matching of casts. While this is the primary method employed a technique of comparison using computer image analysis is also introduced and implemented at an experimental level. Data interpretation involves the discussion of matched timber groups with reference to position, stratigraphy and dendrochronology. In addition, tool reconstructions are presented and compared with known tool finds for the period during which the site was occupied.

The thesis demonstrates that the examination of toolmark signatures is not only achievable but has a useful role in the future archaeological interpretation of Oakbank Crannog and other waterlogged sites.

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CHAPTER 1

Introduction

1.1. Background principles.

Prehistoric worked timbers provide the focus for this study. The data used in this examination are a selection of worked timbers from the late prehistoric site of Oakbank Crannog, Loch Tay, Perthshire, Scotland (see chapters 4 & 5).

The intention of the thesis is to examine the manner in which the traces left by tools during the wood working process can be used to elucidate archaeological relationships. A recent book on the history and prehistory of woodworking technology briefly describes the role of such studies as being to detect: 'le tour de main de l'assassin' (Noel & Bocquet, 1987, 88). Despite the colourful and emotive language, tool marks can indeed be used to establish the work conducted by a particular tool and therefore possibly an individual.

Studies such as these fall into a broader group of archaeological investigations that include the examination of tool marks on all manner of objects. Many of the modern investigations can be seen to stem from the impetus provided by the pioneering work of the Russian Semenov in the late 1950's (Semenov Trans. Thompson, 1964). A common basic principle underlies all such examinations and is outlined succinctly in the following:

'when a given tool is used to shape or to perform other operations upon a second object, or workpiece, it may be expected to leave markings upon that workpiece which, given proper study, can be used to characterise, or in some cases identify, the tool and the manner in which it was used. Conversely, the workpiece can be expected to leave traces - wear - that can likewise be used to characterise and in some cases identify the function of that tool.'
(Campana, 1980, 1-2)

The present investigation is concerned with the traces left on the workpiece rather than on the tool itself. Identification of the work conducted by an individual tool can be traced

through the features called tool mark signatures and it is the examination of these that will be at the core of the current study.

A tool signature is a term coined by Professor J. Coles to describe the ridges or grooves that can be found running down the long axis of a facet on a piece of worked timber. These ridges or grooves have been attributed to: 'any irregularity on the blade, perhaps a chip or bending of metal ' (Coles and Orme, 1978a, 79; see also fig.2.1 this thesis). The term 'fingerprint' has also been used to describe these features (Coles and Orme, 1983, 25). However, for the sake of consistency they will only be referred to as signatures within this project. Furthermore, fingerprints are in their own right the focus of archaeological examination (Åström & Eriksson, 1980).

The pattern of striations produced by a damaged tool can be considered as unique to that tool. Thus, if the same pattern is found on different timbers a relationship between those timbers can be inferred through the single tool used in their working. In other words matches between signatures provide very clear evidence of contemporary manufacture. Crucially, these signals are anthropogenically formed and produce links between timbers that are independent of the natural tree ring cycles that indicate contemporaneous felling (see chapter 16).

At the site of Oakbank Crannog, it is the marks left by axes that are the most frequently encountered on worked wood. Indeed, while other tool marks are considered during this thesis, it is only axe mark signatures that have been found in sufficient quantities to begin the process of associating timbers. Axe marks are particularly important as they are found on in-situ uprights; marks left on in-situ timbers enable spatial relationships to be examined amongst matched groups.

Figure 1.1 demonstrates that an axe can indeed produce a consistent signature. In this case a modern steel blade was used but it serves to show the general principle. The axe has been used to perform a variety of tasks, from spoon making to pile production, and on a variety of

timbers, from hazel to oak. At periodic intervals the tool was driven into a hazel branch and a plaster replica was made of the facet produced (see chapter 9). The illustration shows a selection of these casts, the uppermost cast is a record of a portion of the blade before the work started while the lowermost cast represents the state of an overlapping portion of the blade after a series of blows.

Bends or chips in the blade edge are obviously the source of the striations in a signature. However, the damage is often very subtle even when the signature is quite bold. Plate 1.1 places an axe against the signature it produced. In this case a replica bronze axe has been used. The signature produced by this axe is clear and easily matched when found on different timbers. The axe edge has been positioned so that the points of damage on the blade correspond with the marks they produced. The damage is difficult to identify on the blade even when the ridge produced appears large. It is extremely difficult, if not impossible, to identify the tool used to produce a particular mark by examining the blade alone. The only easy way in which to establish this connection is to use the tool and record the signature produced. It is clear from the experimental work done during this project that ridges and grooves on a wood surface appear larger than the original damage would suggest. This is most likely related to the compression of the wood as the blade strikes which is followed by an expansion of the surface caused by the release of pressure as the blade has passed. Fresh wood, having a higher sap content, may compress and then expand to a greater degree than seasoned wood and this may explain why signatures have been observed to be more clearly registered on freshly cut timber.

In most cases, when a match is exact, the evidence of association established through signatures demonstrates manufacture that is no more than a few hours apart, as sharpening of the tool will alter the pattern of the signature. It is true to say, however, that, if the tool is left unused for a period, matches might be produced between timbers that do not represent contemporaneous manufacture. However, it can be argued that this problem is, in most cases,

more apparent than real. Clearly the axe is not the type of tool that is set aside for long periods of time without use.

The evidence from Oakbank Crannog suggests that there were no especially large axes used for construction. The axes used were more than likely those which were also employed in everyday tasks such as the fabrication of wooden containers or the collection of material from the woodland. The suggestion is that far from being utilised periodically they were in virtually constant use. This is also seen on other later prehistoric sites where it is clear from artifactual evidence that the axe is very much a multipurpose tool. At the site of Fiauvé, Italy, for example, a neatly executed wooden bowl is clearly produced largely with the use of a typical Bronze Age axe of the area (Perini, 1988, 74, Figs. 15-17).

1.2. The archaeological potential of tool marks on wood.

At the most basic level signature matches indicate close temporal associations between otherwise unconnected timbers. However, the application of such associations goes beyond merely stating that two timbers were worked using the same tool. The ability to link up timbers in this manner can potentially have a bearing on a number of site related issues. The following suggests some possible applications for signature links.

Spatial and chronological aspects of construction.

- *Identifying structural patterns.* Signature associations made between in-situ timbers may demonstrate coherent structure amongst otherwise confused material. By plotting the position of timbers produced by particular tools, patterns of otherwise unsuspected structure may emerge.
- *Identifying building phases.* A particular building phase will involve the use of a set of axes. If groups of different signatures can be associated with a particular phase of building, then every time that group, or suite, of signatures is found, structural patterning may be identified belonging to a particular phase of construction.

- *Identifying associations with nearby sites or structures.* Some timbers at Oakbank Crannog are not stratigraphically associated with the main mound of organic material that makes up the bulk of the site. Signature matches may eventually identify the relationship between these timbers and the construction of the rest of the building.

Aspects of data verification and extension

- *Providing independent checks on other techniques.* Signature associations provide excellent evidence of contemporary manufacture. This evidence can, potentially, provide confirmation and enhancement of other information relating to worked timber, such as dendrochronology.
- *Extending information.* Many techniques relating to wooden material require extensive laboratory preparation and analysis. It is possible to use signature information on site, sometimes gaining indications of associations almost as soon as the timber has been uncovered and cast. Such associations will allow for information already established for one timber to be quickly transferred to others. This is particularly relevant to sites such as Oakbank where all the timbers so far examined appear to have been put in shortly after felling.

In addition to the above possibilities, it is also possible on some timbers to reconstruct full blade shape by examining features on the facet that register the sides and blade edge of the tool. Signatures can also be used to extend the number of full blade reconstructions that can be established on a site. It is rare for all of the facet features described in chapter 2 to be present on a single facet. Signatures allow more than one facet to be used to combine information. Each facet is chosen such that the signature patterns overlap allowing features from different facets on the same timber to be combined with confidence (see Chapter 2 and glossary for definitions of facet features).

The complete reconstruction of original blade shape and curvature help clarify the relationships between groups of matched signatures (see Chapters 11 & 12). Blade reconstructions may also enable further questions to be addressed. Such questions include:

Social aspects of construction

- *Suggesting the number of axes/people involved in a particular structure.* The number of signature groups combined with blade reconstructions will to some degree reflect the demography of the workforce involved in the construction (see chapter 13).
- *Suggesting workforce organisation.* The distribution of particular signature groups may reflect the organisation of the workforce undertaking the construction. This aspect has to be approached with caution as it is unlikely that the sequence of pile driving will directly reflect the sequence of cutting.

Technological aspects of construction

- *Reconstructing the functional types of tools in the crannog dwellers' tool kit.*

Typological aspects of tool marks

- *Fitting tool marks to known tool finds.* The reconstructed blade widths and edge curvatures from a site could be linked to known stylistic types.

The above has suggested a number of issues that might logically be examined with the aid of signature matches. The extent to which each of these suggestions can be practically implemented is examined throughout the current thesis, the structure of which is described in section 1.4.

1.3. The scope of the study

The worked timbers from Oakbank Crannog provide all the data for this study. Matches between marks are most likely to occur amongst groups of timbers of the same phase of construction. Within the mass of timbers that make up Oakbank there is a high chance that

groups of timbers will indeed belong to specific construction phases. Tools are resharpened over time and the original signature forms will eventually be lost. Consequently, the chance of associating worked timbers is greater amongst the material from a single site than it is between sites.

Inter-site studies may eventually be conducted; in Loch Tay, for example, there is a crannog site very close to that of Oakbank (fig.3.1, site 4). The date obtained from this site suggests that its construction and occupation may well have overlapped with Oakbank (fig.3.2). In this situation active co-operation in building and repair may be envisaged between the two sites. Given this possibility it would not be at all far fetched to suggest that matches might be sought between the two sites.

Sufficiently extensive examinations of the nearby crannog are, unfortunately, beyond the scope of the current study. Having said this, however, it is clear that the techniques and ideas developed in this thesis will be directly applicable to the other crannogs as and when they receive archaeological attention. Furthermore, the moulding techniques used to record the tool marks will allow for the long-term storage of signature details and thus provide an archive against which future investigations of nearby crannogs can be checked (see chapter 9).

1.4. The structure of the thesis.

Axe marks are the principal type of tool mark examined in this thesis. Chapter 2 demonstrates and defines the principal morphological features of the axe mark and its signature. This chapter also establishes the terminology that will be used throughout the rest of the thesis.

The examination of sites such as Oakbank fit within the wider perspective of wetland and submerged excavation all over the world. Chapter 3 briefly places the Oakbank excavation within this wider context and then gives a summary of the development of crannog investigations.

Tool marks on prehistoric timbers have received varying degrees of attention since the early days of antiquarian enquiry. Over the last twenty years these marks have had more systematic examination, chapter 4 reviews this development. This chapter also gives a brief introduction to the manner in which similar marks have been noted on other archaeological materials and the way this information has been used.

The form, chronology and excavation of Oakbank Crannog are considered in chapter 5. The wooden remains and species used on the site are covered in chapter 6, while in chapter 7 the survival of the tool marks and the nature of the crannog dwellers woodworking tool kit are examined.

Investigation of tool marks at Oakbank Crannog stems from a small pilot project that was undertaken at the Institute of Archaeology, University College London, as part of an undergraduate degree. The original project highlighted the excellence of tool mark preservation on the site. During this project it was possible to demonstrate on a small sample that timbers from the crannog could be associated through the marks left by the tools used in their manufacture. A brief review of this pilot study is given in chapter 8.

The methodological aspects of tool mark examination at Oakbank are examined in chapter 9. In particular, the method and case for in-situ replication of marks with moulding materials is explored. The resolution to which these marks ought to be examined is considered and methods of comparison discussed.

A detailed discussion of core signature groups is covered in chapter 10. These are the fundamental results of the comparison process discussed in chapter 9. Groups of signatures are illustrated which have been found to match extremely closely. The distribution of these groups on the site is presented and the principal features of their signatures highlighted.

Chapter 11 explores the manner in which blade shape and width may be reconstructed from side and jam features (see Chapter 2 and glossary). The reconstructed blades for the Oakbank material are then presented and discussed. This is followed by an examination of the

manner in which these reconstructions may be used to demonstrate that two casts or groups will not match.

Relationships that might exist between core groups are examined in chapter 12. This chapter suggests that some of the core groups described in chapter 10 can be regarded as being the product of the same axe. Considering the conclusions made in chapter 12, comment is passed in chapter 13 on the extent to which aspects of site construction can be investigated; the number of axes used and the nature of the workforce.

Chapter 14 considers the production and uses of signature suites. These are collections of signature groups that can be shown to belong to a particular phase. By utilising groups of clearly associated signatures, phases of construction may be established and patterns of construction made clear.

The possibilities of associating the reconstructed axe blades from Oakbank with known axe finds are looked at in chapter 15. This chapter suggests the form that the Oakbank axes took. In particular the question of whether bronze or iron was used for the tools is considered.

Chapter 16 explores the manner in which tool mark results can be usefully combined with other techniques. This chapter focuses on dendrochronology and looks at the relationship between the tree ring work done on the site and the results from the current study. In addition associations not yet established at Oakbank are considered, such as how would the stockpiling of timbers before construction affect the relationship between the two techniques. Chapter 16 also introduces the concept of the economy of information that may be provided by unequivocal signature matches. In other words, the manner in which information established for one timber can be legitimately transferred to other timbers bearing the same mark.

Additional approaches to the analysis of tool mark signatures are considered in chapter 17. In particular the application of computers and image analysis is examined. This chapter also introduces and discusses the SigMatch program. This program has been developed during the project to test the possibilities of automated signature matching based on digitised images.

Chapter 18 briefly reviews the principal uses of signature information and explores the future application of tool mark analysis at Oakbank Crannog and other sites. In particular the ability to record and use signature information during an excavation season is highlighted. With this information the excavator may obtain essential insights into the nature of the structure being examined, which may help to direct aspects of additional excavation during the same season.

CHAPTER 2

An introduction to facet features and terminology.

A tool mark possesses a number of features that reflect different aspects of the tool that produced it. Many of these features will be referred to throughout this thesis and the following chapter discusses and defines the principal terms used. Marks left by axes predominate on many sites with structural timbers and it is the features that these tools produce on the wood surface that provide the focus for the following discussion.

2.1. Axe mark features.

Figure 2.1 represents the principal features to be found on an axe faceted wood surface. The lower part of the illustration demonstrates the occurrence of these on an artifact, in this case a wood chip from Oakbank Crannog (No.5070).

A facet is defined by either surrounding unworked wood or by the raised areas formed at the junction between successive blows of the axe. At the top of a facet is the **entry heel**. This feature results from the slight shift in angle of the axe blade shortly after entry into the wood. This is possibly a result of the grain orientation as the axe responds to the line of least resistance. Observation of this feature allows immediate identification of the direction of working. This is most usually observed on piles and can be seen on plate 2.1, which shows the faceted surface of pile 1036. The entry heel is demonstrated on at least four facets in this photograph. The change in angle represented by this feature reflects the light more than the rest of the facet and the entry heels appear as lighter lines at the top of the tool marks. The top of the timber is to the left of the photograph and the wood has been worked towards the point, which is to the right.

On the left and the right of a facet **side** features can be present. These are registrations of the ends of the axe blade edge. When registrations of both the left and the right ends of the axe blade are encountered on the same facet the width of the tool can be estimated (see chapter

11). For the purposes of this study it was found convenient to refer to these features as **side 1** and **side 2**. **Side 1** is defined as side registration on the left of the facet when the facet is oriented with the **entry heel** at the top. **Side 2** is defined as side registration on the right of the facet. The use of the terms left and right were avoided to prevent any assumption as to the position of the haft relative to the blade when the piece was cut

At the bottom of a facet a **jam** feature may be present. A poor axe strike often results in the tool becoming jammed in the timber; when the axe is removed, a ragged area of semi-detached wood is left. Careful removal of the flap of wood left by a poor strike reveals the **jam curve** (O'Sullivan,1991,61-62). This represents the exact shape of part or all of the axe edge and can be recorded by tracing onto transparent plastic sheet.

2.2. Signature features.

A **signature** consists of a series of features that run down the long axis of a facet. These features can be characterised as either ridges or grooves. Ridges are areas of the wood surface left up standing by a gap in the blade edge. A groove is produced by an area of the blade where a flange of metal extends beyond the normal plane of that edge. Whereas a gap leaves a ridge of uncut wood, a flange gouges out extra wood leaving a groove in its wake. Obvious grooves are rare features and have only been clearly observed on two pieces from the Oakbank Crannog site (see group WE chapter 10).

A bend in the blade edge can potentially produce a groove or a ridge. The feature produced depends on which face of the blade is presented to the wood surface. If the bend is against the wood surface it acts like a gouge, if it is away from the surface it acts in the same manner as a gap in the edge. Thus, a signature match may be produced where corresponding features are grooves on one facet and ridges on the other.

The form the signature takes on the wood surface in some ways reflects the motion of the tool. On a number of facets the tiny striations making up a signature are seen to curve. It has

been suggested that this curvature may allow for the reconstruction of the length of the tool handle used (Brunning,1991,23). This is based on the possibility that the curvature of the signature represents the arc of the tool as the arm swings down. During a pilot study for the current project it was also considered likely that the curve of the ridges directly recorded the arced motion of the arm as the axe was swung into the wood surface (Sands,1989,39). This is now no longer considered to be a consistent relationship.

Observation during experimentation demonstrated that the curvature of a signature could be counter to the apparent arc of the arm swing. Plate 2.2 demonstrates this possibility; the plate shows the use of a replica bronze axe during the cutting down of an alder tree. The axe head can be seen in the top left hand corner of the picture. The person using the axe was standing to the left of the tree and the axe was swinging from top left to bottom left in the photograph. If the signature on the facet just below the blurred tip of the axe is examined it can be seen to arc from top right to bottom right down the facet; in other words opposite to the apparent curve of the axe swing. This counter curve was not always produced, when manufacturing pile points on the ground, for example, the signature consistently demonstrated an arc that swung away from and then back into the body.

The possible role signature curvature may play in establishing whether the woodworker was left or right handed or in determining the length of the tool handle is an interesting aside but not one with which the present study will become preoccupied. The curved form of some signatures is, however, relevant to signature matching. The distance between signature features, ridges or grooves, is referred to as the **inter-ridge distance**. This distance is not necessarily consistent either along the length of a single facet or between facets. This can be seen to be the result of the blade travelling through the wood at an inclination that is not at right angles to the direction of force. The variation in **inter-ridge distance** is demonstrated in figure 2.2.

Most signatures will display some degree of compression in width resulting from the angle of strike. This is especially true when socketed axes, hafted using the naturally occurring

angle formed between a stem and its branch, are used (Coles & Coles,1989,fig.72). In this case the axe blade is not at a right angle to the haft and its association with the strike direction is complicated.

The compression of inter-ridge distances does not present too much of a problem when visual matching of signatures is being conducted. Between facets the variation is not usually so great as to produce major difficulties. Figure 1.1 illustrates this well; all signatures clearly match but subtle variation is apparent. The only occasion where it can produce significant error is when blade width is being reconstructed solely on the basis of side registration (see chapter 11). It can also present a problem when computerised signature matching is being contemplated (see chapter 17).

CHAPTER 3

The context of the current investigation.

Waterlogged material is an increasingly common fact of archaeological discovery. Well-preserved wooden artifacts have been found at numerous sites throughout the world. The following chapter briefly introduces the wider context within which the current project fits. A more detailed background to crannog studies is also given, which places the data from Oakbank Crannog in its local context. From the latter consideration it is suggested that within Scotland alone there is such a wealth of organic material that the methods and techniques developed in this project will have a much wider application.

3.1. Wetland and submerged sites - the wider perspective.

The Scottish crannog sites that are discussed below and which are at the core of the current study are just some examples of the type of well-preserved waterlogged material that has over the years become an increasing part of archaeological discovery and interpretation (Coles & Lawson,1987;Purdy,1988;Coles & Coles,1989;Coles,B.,1992). These finds cover a broad chronological and geographical range; from American Indian sites, such as Hontoon Island in Florida (Purdy,1988,325-335), to many Bronze and Iron Age sites in Europe, such as Cortaillod-Est, in Switzerland (Arnold,1986) or Biskupin, in Poland (Niewiarowski et. al., 1992), through Mesolithic sites, such as Tybrind Vig, in Denmark (Andersen,1985; Andersen,1987), to Palaeolithic and other sites in Japan (e.g. Matsui,1992; Noshiro et al.,1992). All such sites provide the organic preservation that has, until recently, been so often missing from archaeological investigation.

The work conducted on waterlogged sites is not merely an exercise in collecting an ever increasing number of spectacularly preserved organic artifacts. Similarly the results from these sites are not just an adjunct to environmental archaeology as some people have clearly perceived (Tilley,1991). Indeed, as Coles has pointed out:

'wetlands will, in almost every case, yield more and more varied types of evidence than will a dryland site where desiccation has occurred. In terms of archaeological yields, therefore, wetland sites will be more akin to those ethnographically-recorded settlements where organic structures and smaller artifacts were the dominant elements in material culture' (Coles,J.M.,1987b,10-11)

The preservation of organic material provides a whole range of additional information for the archaeologist. The survival of wooden material on such sites provides a useful insight into one of the principal materials used by past societies. Examination of this material enables the manner in which it was used to be more fully assessed and the form of objects and structures to be more completely envisaged.

The discovery of wooden elements of house structure has allowed for the detail of past construction techniques to be examined. In addition this has enabled the finds of tools that conducted the work to be placed into a context that extends beyond the merely typological. At a number of sites the discovery of such material has encouraged experimentation into ancient woodworking techniques and tools. At the Late Bronze Age site of Fiavé, Italy, for example, the conditions have preserved not only a considerable number of domestic wooden objects, within an occupation context, but also detailed information on the construction techniques of the housing (Perini,1984). The discoveries on the site have led to a practical consideration of the manner in which the various tools found actually functioned (Perini,1988,48-49;67-77). Such examinations have been conducted at a number of other wetland sites. The Somerset Levels Project, for example, has conducted regular experimentation, references to which can be found throughout their publications (e.g. Coles & Orme,1985). Similar studies at the Late Bronze Age site of Flag Fen, Peterborough, have also led to a more complete understanding of the nature of the construction (Taylor & Pryor,1990; Pryor,1991,77-81). In these and other areas such research has been extended to full scale reconstruction and exhibition (e.g. Ruoff,1992).

The examination of material from such sites not only allows for the reconstruction of additional elements of material culture, it can also allow for the precise determination of site

building, repair and abandonment. The recording of tree rings has allowed for both relative and absolute chronologies to be constructed for numerous sites with wooden material. At the Neolithic site of Charavines, in lake Paladru, France, for example, a detailed relative chronology has been built up. This chronology demonstrated the sequence of construction, alteration and abandonment of a series of houses over a period of sixty years (Bocquet et al.,1987,51-54).

Wooden material from the Late Bronze Age settlement of Cortaillod-Est, Lake Neuchâtel, Switzerland, has also enabled a chronology to be constructed but at this site it was possible to establish the precise dates of building. The site was begun in 1010 BC with sporadic repairs continuing until 965 BC at which point the entire settlement was rebuilt closer to the present shoreline (Arnold,1986,11). Some interesting patterns might be revealed on these and other sites when the dendrochronological conclusions are combined with those that might be established through signature matches (see Chapter 16). It is clear from illustrations of timbers from Cortaillod - Est that the techniques described in this thesis may be applicable to at least some of the material from the site (e.g. Arnold,1986,114,fig.115).

A number of other reports on waterlogged sites also illustrate, or make reference, to tool marks on the surfaces of the timbers found. In many cases these are merely passing references but occasionally more extensive work has been conducted (see chapter 4). While comments are sometimes limited it is clear there is considerable potential for tool mark survival. Consequently, it can be argued that the techniques and ideas presented for Oakbank Crannog may have a much broader application within archaeology. This is especially true of the type of submerged or wetland settlement sites where in-situ structural timbers are still present and spatial relationships are sought.

3.2. Crannogs - a background

3.2.1. A definition?.

The current study is based around the Oakbank Crannog site, which is located on the northern shore of Loch Tay, Perthshire, Scotland (fig.3.1). Crannogs are wholly, or at least partly, artificial islands found in many, if not all, Scottish and Irish lochs (Dixon *passim*.; Morrison,1985). In addition to those found in loch contexts many artificial islands have also been located in estuarine situations around Scotland (Hale,1992).

The precise definition of a crannog either in terms of construction or chronology is not straightforward. The construction of crannogs has in the past been described as "packwerk", based on investigations of artificial island sites in Ireland (Davies,1942,20). The construction of such sites, using the "packwerk" model, involves the dumping of layers of brushwood, timber, stones and other material to provide a platform, in the water, which is retained in place by a close-set ring of piles; for some this provides the basis for the definition of a crannog (Lynn,1983,50-51). Indeed, a few writers still consider this as an unvarying feature of their construction:

"They are always built with solid foundations of timber, peat brushwood or stones, dumped on the loch or river bed or used to extend a natural island" (Barber & Crone,1993)

However, a dogmatic adherence to this kind of definition must be treated with caution, given the limited number of sites that have been closely examined. While the excavations at the site of Buiston crannog appear to show a "packwerk" construction resting on a series of neatly laid turfs (Crone,1991), excavations at Oakbank Crannog have revealed a structure that was at least a free standing pile dwelling in the early stages of its existence. The free standing nature of Oakbank is both archaeologically clear and independently suggested by dendrochronological results. Work by Dr. Crone on a selection of timbers from Oakbank has gone some way to demonstrate a deposition of wood over time rather than the single phase

dumping of material suggested by the "packwerk" model (Crone,1988,170). In consequence it seems fair to say that:

'A definition of crannogs cannot at present be too firmly formulated owing to the lack of information regarding visible structural elements' (Dixon,1982b,17)

and that a:

'Classification of crannogs into different groups by style, region or period is equally ineffective' (op. cit.,18)

The use of artificially constructed islands appears to have been a common occurrence across much of Scotland over a broad chronological range. An increasing number of radiocarbon dates have begun to illustrate the nature of this range (fig.3.2)

3.2.2. Previous approaches to site investigation.

Mention of crannog sites in Ireland and Scotland is to be found mainly from the first half of the nineteenth century onwards. Most early records were, however, merely passing observations or accounts of relic collection (Dixon,1991,1). However, the publication, from 1854 onwards, of a collection of accounts of sites in the Swiss Lakes, by Dr. Ferdinand Keller, stimulated more systematic examination of lake side sites, especially in Scotland.

By the time Keller's work appeared in its first English edition it included a 'Notice on Scotch Crannogs' by John Stuart. This work was based on the examination of a number of sites revealed after the drainage of the Loch of Dowalton, which Stuart visited at the invitation of Lord Lovaine in the early 1860's (Stuart,1865). Stuart's study was the first comprehensive examination of Scottish Crannogs (Dixon,1991,1).

Keller's reports also inspired Dr. Robert Munro to examine the crannogs within the lochs of his native Scotland. Starting with Lochlee Crannog, in Ayrshire, he began the excavation of a series of crannogs that were to form the core of his book "Ancient Scottish Lake Dwellings or Crannogs", published in 1882. These examinations were clearly not conducted with the rigour of modern excavation methods and much material failed to be recorded

(Dixon,1991,2). However, his work did at least include a consideration of both the structures of the sites and a certain degree of stratigraphic description. Indeed, it is to his considerable credit that this work still provides the starting point for all the more recent crannog investigations (e.g. Dixon,1984b; Crone,1988). Certainly, without his careful examination all the information contained within the crannog mounds would be lost through the decay of the now desiccated sites (Barber & Crone, 1993).

All the sites that received close examination from Munro in the late eighteen hundreds were ones that had become exposed through the drainage of lochs to provide for additional agricultural land (Morrison,1985,5). Examinations of submerged sites were, however, attempted in the last century. Notably the study of structures in the Swiss Lakes provided the earliest example of attempts to observe material that was not exposed by fortuitously low lake levels. In lake Geneva, in 1854, Adolphe von Morlot, a geologist, utilised a glass fronted bucket that was attached by a hose to a pump on the surface, to retrieve objects using a net and a pick.

Early attempts were also made in Scotland to examine submerged sites. In 1867 the Reverend R.J. Mapleton, used professional divers to investigate the crannog in Loch Kielziebar (Mapleton,1867). However, the investigations made were superficial and Mapleton was unable to verify the observations himself. At the beginning of this century more concerted efforts were being made to examine sites underwater. Father Odo Blundell, donning a diving suit loaned to him by Caledonian Canal divers, was able to observe for himself the submerged form of a number of crannogs (Blundell,1909). Useful though these observations were, Blundell was still not able to explore the structure of these sites by excavation.

The loss of both Munro's and Blundell's active involvement at the start of the First World War removed much of the previous impetus from crannog investigations. Indeed, between 1917 and 1952 there were only two reports produced of two superficially excavated crannogs; that at Coatbridge (Monteith,1937) and that at Eadarloch (Ritchie,1942). Mrs C.M. Piggott's

investigation of Milton Loch I crannog, Kircudbrightshire, in 1953, was the first more extensive and rigorous excavation since the time of Munro. During this excavation a complete floor plan for at least one phase of the building was revealed (Piggott, 1952-53). However, like Munro's investigations, Piggott could only access those parts of the site that were exposed as a result of lowered water levels (op. cit., 134-135). Thus, despite 'modern conditions of enquiry' (op. cit., 147) the excavation could only scratch the surface of the information that potentially lay within the body of the crannog mound. Indeed, for a long time the structure was considered to be a house of the 2nd century AD on the basis of artifactual evidence. This reinforced the image of an island refuge as a response to:

'the unstable conditions obtaining between the two Roman walls in the 2nd - 3rd centuries AD.' (op. cit.)

While there may well have been activity on the site at this date, radiocarbon determinations have shown that one of the in-situ piles dates to around the middle of the first millennium BC, as too does an ard found within the structure of the building (Morrison, 1981; Guido, 1973). Indeed, it may be no coincidence that the earliest dates yet recorded for a crannog come from piles deeply set within the Oakbank site, considering that this is the only submerged site that has had systematic examination (see below).

Without the use of diving equipment crannog investigations still had to rely on the occasional fortuitous exposure of the sites. In 1960 a crannog was uncovered in Loch Glashan when a hydro-electric scheme lowered the water level by 4 m. The site was excavated by J.G. Scott but like the examinations mentioned above he was only able to study the area that had been exposed by the drop in water level (Scott, 1960).

3.2.3. The development of underwater investigations.

Father Odo Blundell's underwater investigations of a number of sites indicated a way in which crannogs could be examined without drainage or the lowering of loch levels. Innovative though Blundell's studies of crannogs were, they still only touched upon the potential of

underwater examination of these sites. Bulky and labour intensive early diving equipment prevented serious attempts at excavation underwater (Dixon,1991,3). With advances in diving equipment and the development of modern archaeological techniques the extensive study of Scotland's artificial islands has become a practical possibility.

Initially, diving was utilised in a surveying role. Underwater examination of a number of lochs around Scotland in the early 1970s, by the McArdles and Dr. Ian Morrison, confirmed the extensive presence of crannog structures. This work included a detailed survey in Loch Awe, in 1973, that revealed a number of hitherto unknown sites (McArdle, C. & D. & Morrison, 1973).

From the 1960's underwater investigations of Swiss sites had also been developing. In particular work by Dr. Ulrich Ruoff in the lakes around Zürich led to the development of a number of techniques. These developments ensured that underwater excavation of submerged settlement sites could be: 'recorded and interpreted to the same high standards as land based archaeologists expect' (Ruoff,1980,151).

Techniques such as those developed by Ruoff were incorporated into the first real innovation in crannog investigation since Munro and Blundell's day. In 1980 a controlled underwater archaeological excavation of a crannog was started by Dr. T.N. Dixon (Dixon, *passim*). This ongoing excavation and its associated survey (Dixon,1982b) conclusively demonstrated that many of the stony mounds in Highland lochs were originally entirely timber constructions. This finally dispelled the neat image produced by Munro of a division between timber constructions of the south west of Scotland, the 'true' crannogs, and the stone constructions in the Highlands. An image that had persisted right through to Piggott's investigation of Milton Loch (Piggott,1952-53,147).

Highland crannogs have in the past been considered to have had only a limited function. When Piggott wrote her report on Milton Loch I, for example, she made the comment that:

'Many of the highland examples can only have been refuges, for with few wild-fowl and no land on shore suitable either for pasture or corn growing, it would be impossible to live regularly in such places' (Piggott, 1952-53, 147)

The quality of preservation, the use of underwater excavation techniques and the application of environmental analysis at Oakbank have demonstrated just how far from the truth this may be for some sites. Not only has a wooden plough survived, cultivated cereals have been identified and the presence of sheep on the site has been attested to by the survival of their droppings. The whole site gives the impression of a well-used dwelling with evidence of numerous activities from stock keeping to cultivation. There are even clear signs of the use of dairy products with the remnants of butter being found within a carved wooden container.

The excavations at Oakbank have also revealed the excellent preservation of wood working marks. The story that may be told from these is the basis of the current study.

CHAPTER 4

Previous commentaries on tool marks.

The following chapter gives a summary of the manner in which tool marks have been reported in the antiquarian and archaeological literature from early observations to the present day. It is concerned principally with comments made about waterlogged wood as this is the material about which the current project is concerned. However, a short section is also included that demonstrates the manner in which similar features have been observed and recorded on other materials.

4.1. Tool marks on waterlogged wood.

4.1.1. Early commentaries.

Tool marks on ancient waterlogged timbers have been commented upon since the earliest days of antiquarian enquiry. In 1699, for example, James Fraser commented on some timbers that he had found buried deeply within the eroding banks of the Beaulieu Firth noting that one of these: 'carried the mark of an ax on it' (Anderson, 1967, 63).

In most early references to worked timbers the mention of the woodworking marks served as little more than a device to illustrate the excellence of the preservation encountered. In the following extract, for example, timberwork from the site of Dorman's Island, Whitefield loch, Wigtownshire, is described:

'several of the beams show mortise holes neatly cut, some of them about 7 inches square. In some of the smaller ones pieces of the broken mortises still stand upright. Two or three short stakes were pulled up. They show at first a glairy covering of a golden yellow. When this is washed off the small axe marks are found quite fresh, and the grain of the wood is beautifully distinct.'
(Wilson, 1871, 375).

A few early examinations of wooden material attempted to characterise the nature of the worked timbers a little more closely. Some writers put forward their opinion as to the nature

of the tool that had been used. In particular the issue of whether a stone or metal blade had been used is addressed in many of the reports. Most of these observations were no more than passing notes that did little to characterise the nature of the differences observed. The comments made by Angus Smith concerning waterlogged material around Loch Etive are a good example of the type of remark made:

'The young trees had been felled with a sharp axe. There was none of the clumsiness of the stone age'. (Smith,1871,94)

Some commentators made more descriptive remarks as to the nature of the cuts observed. John Mackinlay's account of piles he found on a crannog site in Dhu loch, Bute, refers to the form of the facets found:

'I took out one of the larger piles of the original edifice ... the point seems to have been cut by a celt, or stone axe, as the cuts were hollow, or as it were conchoidal.'
(1857,43)

Similar observations were also being made in other parts of the world. In Gastaldi's account of a site found in the turbary of Mercurago, Northern Italy, for example, he commented on the tool marks on one of the piles found. In this account the form of the tool was addressed and he concluded:

'that the instrument used in sharpening it must have had its cutting part in a curved shape as the traces it left are sensibly concave.' (Gastaldi,1865,103).

Many early comments about woodworking marks relied solely on the opinion of the excavator and no attempt was made to verify the observations made. However, typically, the work conducted by Ferdinand Keller and his colleagues in the Swiss lakes demonstrated a higher attention to detail than many of their contemporaries. At a site in the locality of Meilen, on the lake of Zürich, for example, Keller was also interested in establishing the type of tool that had been used to fashion the piles that had been drawn up. The question of stone or metal implements was again at the forefront of the enquiry. To resolve this matter Keller showed five of the best preserved piles to a number of joiners and carpenters. The opinion of these woodworkers was that:

'the nature of the strokes the hewing or rather hacking of the points, indicated very clearly the use of a stone hatchet, and that no tool of any kind of metal, nor any usual tool of carpentry had been employed about the work' (Keller,1878,23).

In fact Keller went further than this employing experimental tests of the actual tools found in the area:

'In order to test the possibility of working timber with such tools and to prevent any doubt which might arise, we had several trials made with these stone implements, and they have convinced us of the correctness of the conclusions arrived at.' (Keller,1878,23)

Some workers in Switzerland attempted to go beyond the stone/metal debate. Dr.F.A.Forel made some comments concerning the exact form of the tool. This went further than a mere discussion of functional types and into the question of linking woodworking to known stylistic forms. In writing about the examination of material from the waterlogged prehistoric settlement close to the town of Morges, Lake Geneva, Forel makes the comment that:

'the piles which have been drawn up at Morges all appear to have been sharpened by small metal celts similar to those we have found' (Keller,1878,297)

At the nearby settlement site of Roseaux, Forel also commented that:

'The piles are of oak and fir; they have been hewn with a bronze celt, and the cutting marks left upon them enable us to decide they were brought to a point by means of the spatula like celt or hatchet mentioned above, and not by the great bronze celt with ears' (Keller,1878,300).

The extent to which the style of tool can be reconstructed from the tool mark is an issue that is examined more fully in chapter 15.

Connections with the actual tools used had also been made in Ireland. The discovery of a wooden construction, in the Drunkelin bog, Co. Donegal, in 1833, by Captain W. Mudge, led to a number of observations on the woodworking. In particular it was noted that:

'the mortises were very rough, as if made with a kind of blunt instrument, the wood being bruised rather than cut, and it may be inferred that a stone celt found lying upon the floor of the house was the identical tool with which the mortises had been formed. By comparing the chisel with the marks of the tool used in making the mortises and grooves, it was found to correspond exactly with them, even to the slight curved surface of the chisel; but the logs had evidently been hewn with a larger instrument in the shape of an axe, undoubtedly of stone, as the marks, though

larger than those the chisel would have made, are of the same character, being somewhat hollow and small cuts, not presenting the smooth surface produced by a common iron axe.' (Wood-Martin,1886,40)

Many early commentaries referred largely to the presence of marks left by axes. However, on some occasion other tool marks were noted. Dr. Robert Munro, in his investigations of Lochlee Crannog, Ayrshire, for example, described a carved trough:

'About halfway between the margin of the crannog and the circle of stakes surrounding the log pavement, and 5 feet deep, the workmen discovered, amongst brushwood and chips of wood, a beautiful trough cut out of a single block of wood. It was quite whole when found, and showed very distinctly the markings of the gouge-like instrument by which it was fashioned' (Munro,1882,93)

A similar trough has been found at Oakbank Crannog and, like that at Lochlee, has holes in its base as well as excellently preserved tool marks. These marks even preserve the signature of the gouge. The excellence of tool mark preservation in both cases also suggests a similarity of use (see section 7.1.1).

None of the early commentators mentioned above make any reference to tool mark signatures. However, the presence of these features was noted on at least one occasion in the last century. The tool marks on a Neolithic tool handle, found in 1897, in a peat bog in Sigerslev, Zealand, Denmark, were described in detail. The description included the following remarks:

'every cut has left a remarkable mark and vertical on these cut-marks are small slightly elevated stripes due to irregularities in the edge of the axe' (Translated from Blinkenberg,1898,131).

That other workers around the turn of the century were aware of the production of signatures is obvious from a number of reports. Mann for example makes particular note of the smoothness of the facets he examined in Wigtonshire and concluded that the tool used had a: 'clean unbroken cutting edge' (Mann,1903,381). This observation is echoed in Smith's report on the so called crannogs in Holderness, Yorkshire (Smith,1911,601 & fig.8). However, while the presence of these marks was certainly looked for and noted by early writers if the manner in which they might prove useful was realised it was not mentioned.

4.1.2. More recent tool mark observations.

Many of the waterlogged sites examined over the last few decades have well-preserved tool marks and some comments have been made about these when the sites are discussed. Often, however, like the early comments, these are only passing references.

A number of sites have been found in and around the lakes and rivers in Northern Greece and Southern Albania about which comments on woodworking have been made. At the site of Maliq, for example, close to the river Devolli, Southern Albania, Frano Prendi comments that marks on the tips of many of the piles show clearly the traces of working by metal tools (Prendi,1966,270). These marks are considered to illustrate the influx of early copper using peoples (Hammond,1972,229) and contrast with those left on stakes found in the earliest level of the Middle Neolithic site of Dunavec, just to the south east of Maliq, the tips of which were: 'worked with stone axes' (Prendi,1982,205).

The comments above are interesting asides but do not consider the examination of the marks in any great depth. On some sites, however, over the last two decades, the observation of tool marks on wooden material has become both clearer and more systematic.

In Britain the work conducted by Professor J. Coles and his colleagues on the tracks and other structures found in the Somerset Levels is of particular importance. Their careful recording has allowed for the observation of many fine details of woodworking practice across a range of sites, of various ages, over an extensive area.

The Somerset Levels project is particularly noteworthy in the context of the current study for its references to tool marks with signatures. For example, during their excavation of the Tinney's track (c.1100-1000 bc) comment is made that a small amount of the waterlogged material: 'carry facets with sets of scratches and ridges imposed upon the smoothed wood' (Coles & Orme, 1985, 44). This finding was pushed to its logical conclusion of matching up different timbers that had been worked by the same tool. Using similarities between signatures on different timbers they were able to clearly link together four pieces of

roundwood that bore the same mark. Perhaps more importantly they were able to observe a 'probable' pairing that could link two of the trackways running across Tinney's ground, that of Tinney's A and Tinney's D (op. cit.)

Observations of this nature began to demonstrate the potential of signature links when dealing with in-situ structural material. Furthermore, close examination of some of these timbers and the orientation of the signatures on their facets also led to some subtle observations about the precise working of the timber. In particular Coles made note of the process by which a particular point was reduced, with observations on the occurrence of forehand and backhand strokes (Coles & Orme, 1985, 44). The examination of the tool marks on the Tinney's Ground trackways led Coles to comment that:

'it is this kind of evidence which brings the actual workmanship closer to us today, and its implications for linking areas of activity are clear.' (op. cit.)

The Somerset Levels project also found similar marks during the excavation of the Meare Heath track (c.1300-900 bc), and some signatures were found on beam surfaces. Although in this case no links were noted, interesting comments were made about the implications of signature use. In particular it was noted that such marks may represent contemporary working: 'even closer in time than the year or half-year deduced by tree-ring analysis' (Coles, J.M. et al., 1988, 14). Furthermore, it was also noted that for broadly single event constructions, such as trackways, the study of signature links might not be essential but: 'for other structures such as buildings or sets of buildings the implications are considerable' (op. cit.). The exploration of this assertion provides a basis for the examination of the Oakbank material. The crannog site represents just such a multiphase construction within which a confusion of timbers exists.

Tool marks and signatures were also being observed in other parts of the world during the late seventies and early eighties. Signatures were, for example, found on the timbers from the large Neolithic settlement of Alvastra, Sweden. On this site Matts Malmer observed that two

small hazel stakes bore the same signature and were, therefore, chopped: 'with the same axe which had a notch in its edge' (Malmer,1978,154,fig.2).

Although the comments on the Alvastra material were presented as an interesting aside it is worth reflecting on the fact that this represents the use of signature linking amongst material worked with a stone blade. Such a possibility is echoed in the illustration of piece SWC55 from the Sweet Track, in the Somerset Levels (Coles & Orme,1984,12,fig.12). The observation of clear signatures left by stone tools may thus make it possible to extend many of the comments made later in this thesis to Neolithic sites with wooden material such as that found in Loch Olabhat in the Outer Hebrides (Armit,1991). Indeed the timberwork so far recovered from this site has been described as having very good preservation with clearly preserved tool marks (Skinner,1989,19).

Tool marks were also being observed on iron age structures in the Dutch Polders during the early eighties. Work by Taylor, as part of the Asendelver Polders project (Therkorn et. al.,1984,363-367), concentrated on the examination of tool marks from an early Iron Age structure. The finds of signatures were not particularly common on this site (op. cit. 365) and Taylor focused her examination on the recording of tool edge width and shape. Using these criteria alone a number of blades were identified with the suggestion that some of the marks were produced by the same tool. The examination of these features of a facet is an important aspect of tool mark studies and when combined with signature information can increase the interpretational value of the study as a whole (see chapters 2,11,12,14).

More recent research has concentrated on the technological aspects of the tool mark and the possibilities of identifying the type of tool used. Work by Aidan O'Sullivan, for example, has helped in the interpretation of the woodworking on trackways in Ireland (1991). In this work O'Sullivan established a series of methods that could be used to consistently record the woodworking attributes of prehistoric trackway structures in Co. Longford, Ireland. The material he examined came from sites ranging in date from the Neolithic through to the Iron Age. By utilising attributes such as facet length and width, O'Sullivan was able to distinguish

between the woodworking of different periods. Of particular interest were the sites that contained well-dated worked wood that covered a period in which the material used to make the tools changed. The Corlea 6 trackway has been dated to around 2259 BC by tree-ring analysis. The **facet junctions** on the wood from this site were clean and sharply defined while the facets were predominantly flat or slightly concave (O'Sullivan,1991,91-92). These attributes indicated the use of metal blades on the site and, given the date of the site, this conclusion was considered to be of: 'considerable significance for the origins of metallurgy in the west' (Raftery,1991,31).

The ideas presented in O'Sullivan's work have been applied to prehistoric worked wood found during excavations in the Severn Estuary (O'Sullivan pers. comm., Nayling pers. comm. & Brunning,1991). None of this work relates specifically to signature related associations due to their poor survival on these sites. It is thus considered that the present work compliments that done by O'Sullivan rather than presenting a conflicting view of the uses to which tool marks may be put in archaeological contexts.

4.2. Tool marks on other materials

While wood provides the focus for the current study it is worth reflecting that other materials also preserve tool marks. The following section introduces a few examples of these other material types.

A number of references exist to both the axe and the adze being used on chalk. Mostly the comments made have been cursory, merely making reference to the presence of tool marks. On occasions the form of the original tool has been suggested, as at the Late Bronze Age settlement of Itford Hill. Marks noted in the base of a pit from this site are assigned to the work of a bronze palstave (Burstow & Holleyman,1957,177). This suggestion, however, derives from the excavator's opinion rather than from experimentation or direct comparison of facet form and shape.

Attempts have been made in the past to categorise marks on chalk more closely. At the Bronze Age enclosure site on Ram's Hill, Berkshire, for example, tool marks have been carefully recorded with tool edge and facet profiles being illustrated (Bradley & Ellison, 1975, 90-91). The authors went as far as to comment that individual tools may be identified and that further observation from a completely excavated site might help in interpreting how the building of the site was organised.

While the work at Ram's Hill suggests that the examination of tool marks on chalk could be taken further, it is clear from personal experience that these do not give the same resolution of information as those found on wood. While signatures will certainly be produced on chalk when it is worked it is highly unlikely that they will survive solution and abrasion effects. Furthermore, the edges of a tool are not as cleanly or as definitely registered as a result of the manner in which chalk fractures and erodes. Consequently, it is difficult to envisage how much further observations of this sort can realistically be taken.

The recording of marks on chalk is important in at least one respect. Such marks suggest that tools, that might ordinarily be considered solely for use in woodworking, have a much broader range of uses on certain prehistoric sites. Clear axe marks have, for example, been found on the sides of the Wilsford shaft, a later Bronze Age site in Wiltshire (Ashbee, Bell & Proudfoot, 1989, 33-35); while the use of iron adzes has been suggested for the production of some of the pits at the Iron Age hill fort site of Danebury, Hampshire (Cunliffe, 1977, 201).

Personal observation of the interior of post holes at the Bronze Age hut platform site at Mile Oak Farm, on the chalk downlands of Sussex, also suggests that tools were used for purposes other than woodworking. The restricted access presented by the hole indicates the mounting of the blade on the end of a straight haft in a similar manner to a chisel.

While tool signatures do not survive on chalk they are clearly present on other materials. Such detail can, for example, be noted on a Neolithic bone artifact from Switzerland (Clutton-Brock, 1991). Signatures on the Swiss bone find are not specifically mentioned although they

are clearly present in figure 3 of the article. Tool signatures have been more explicitly noted on bone artifacts from the British Isles (Olsen,1988c). In researching the possibilities of distinguishing tool marks made by stone from those made by metal on bone finds from a range of sites, Olsen also noted the presence of signatures that might be used: 'to determine if two tools were made about the same time' (op.cit.,349). The occurrence of this feature within the study was too minimal for the logical extension of this observation; future bone finds may, however, prove to be more profitable.

Tool mark signatures have also been found on metal artifacts. These marks have been used to extremely good effect in Benner Larsen's study of the Gundestrup Cauldron. Larsen's study was of particular interest for the current investigation as it brought together a number of the possible uses of tool mark information. On the one hand he examined the form and function of the tool and on the other he managed to group together marks produced by the same tool. To do this he utilised moulding materials to more easily examine the intricacies of the worked metal surface of the Gundestrup Cauldron (see section 9.1). Using this technique and Scanning Electron Microscope (SEM) images, Larsen was able to conclude that a minimum of three different sets of punches were used in the decoration of the silver plates that made up the cauldron (Larsen, 1987, fig.16). Larsen clearly saw the key role of such studies as being to:

'unambiguously link different finds because they bear traces of the same identified tools' (Larsen,1987,407)

Larsen's study is in many ways more akin to the present investigation than many of the studies of wooden material mentioned in the last section.

While the study of the Gundestrup cauldron is similar to the current investigation three important differences can be noted. Firstly, Larsen's investigation considered the use of punch marks. Punches present the whole of their working head to the surface of the material being worked. Indeed, the tool is specifically designed to leave an impression of its working surface. The axe by contrast is periodically resharpened and leaves an impression of its edge that is

smeared down the long axis of the facet produced reflecting the motion of the tool. Secondly, the cellular structure of wood effects the resolution of the detail of the axe edge (see section 9.1.4.). Finally, the type of marks investigated by Larsen will be found on small portable items. They will reflect the work of particular smiths and may enable manufacturing and distribution questions to be addressed. The marks left on structural timbers enable a different set of questions to be asked which may reflect a number of aspects of site construction (see chapter 1). All three of the factors outlined above necessitate different approaches to the examination and interpretation of tool marks on wood.

CHAPTER 5

The site of Oakbank Crannog

The following chapter discusses Oakbank Crannog; its overall form, principal structures, stratigraphy and dating. This provides the background to the data examined during the current study.

5.1. Location and construction.

Oakbank Crannog is located at the northern end of Loch Tay, Perthshire, just off-shore from the village of Fearnan (National Grid Ref. NN 726442). It can be classified as a Late Bronze Age/Early Iron Age dwelling structure and is one of 17 possibly similar sites so far identified in Loch Tay (Dixon, 1982b; Fig. 5.1).

Despite uncertainty as to the precise water level in prehistoric Loch Tay there is no doubt that when Oakbank was occupied it was surrounded by water. The remains demonstrate that the site originally stood on piles over the water with access to the shore being provided by a wooden causeway (see below). It is clear that the piling supported a platform made up of lengths of roundwood timber, parts of which still survive. The upper structure of the building is less clear from the archaeological remains but it is likely that the platform supported a circular hut. The elements of the collapsed wattle work walling still survive as too does a small fragment of daub. The precise manner in which the various elements of the structure were attached to each other is not completely clear. Both mortice holes and knotted hazel ties have been found but no structural timbers have yet been recorded jointed together.

The locations of most of the crannogs in Loch Tay, including that of Oakbank, clearly relate to areas of the loch where slopes are less steep. Dr. Dixon has suggested from this:

'that suitable land for cultivation was a major factor influencing the choice of site for the crannog builders.' (Dixon, 1984b, 173)

Furthermore, it is also noted that:

'Of the seventeen sites in Loch Tay all but one (6) are close to substantial areas of land under cultivation at present.' (op. cit.; and see fig.3.1)

The motive for building crannogs is a question that has been addressed by a number of people and will not be pursued at length in this thesis (e.g. Dixon *passim*; Crone, 1988, 31-33; Morrison, 1985). The reasons will probably have varied with location and date. What can be said is that there are some advantages to living over the water. Defence is the one explanation that has been commonly put forward, however, this is unlikely to be the whole answer. A crannog dwelling would, for example, give easy access to fresh water, fish, transportation and provide a convenient means of disposing of rubbish. Furthermore, by building the house over the water, valuable flat agricultural land close to the settlement would be left free.

Construction of the site may have been at least as easy as a similar sized site on land. Some experimental work conducted during this project suggested that the manipulation of large timbers would be far more easily accomplished in water. Piles could be floated out to the area where they were to be used. Once in position sharply raising the upper end of the pile puts a sufficient amount of the timber below the water surface to sink the point to the loch bed. When in this situation the pile can be easily moved to the exact point for driving. Driving can be accomplished, in the silts of Loch Tay, by little more than a heavy rock although to ensure that the pile tip reached firm foundations some greater force would be required. Once the structure was complete, its own weight would also drive the piles further into the loch bed.

5.2. Investigation.

Oakbank is the only submerged crannog site to have been excavated in Scotland. The site has not yet been fully excavated and there remains as much as 75% of the material still in-situ.

As demonstrated in the chapter 3, examination of crannogs in the last century and beginning of this century could only assess the sites at a superficial level. The underwater

examination of the Oakbank site by Dr. Dixon has demonstrated that submerged archaeological excavation of crannog sites is a practical possibility. Without the ability to examine the submerged elements of crannog structure future investigation of these sites would have to rely, as was the case in the past, on chance drainage. Drainage not only biases which sites are looked at but may adversely affect the material being examined. Once the water is removed the wood can dry out, cells collapse and the fine details degrade. Furthermore, without the supporting action of the surrounding water much of the weight of the object is entirely borne by material in lower levels leading to crushing and distortion (Dixon,1989,53).

The methods of underwater excavation used at Oakbank are well described elsewhere and will, therefore, only be briefly covered here (Dixon,1981a;1982a;1984;1989). The site is totally submerged and all excavation is conducted using diving equipment. The shallow water, 4-5m maximum, allows prolonged periods of work, sometimes more than 3 hours at a time. There is an unlimited supply of air provided for the diver through a flexible hose attached to a low pressure compressor situated on a platform close to the site. To avoid damage to the delicate organic material no fins are used by the divers and movement from one part of the site to another is achieved by walking across the loch bed around the crannog.

Excavation is generally conducted using a dredge that uses water pressure to suck away the spoil as work proceeds. Planning is conducted at 1:1 using wax crayon on 1m x 1m Perspex sheets that are located relative to known control points; these are then reduced to a manageable scale on shore. In most other respects the excavation is much like that on land; utilising trowels, buckets, tapes, finds bags and notebooks.

5.3. The form of Oakbank Crannog

Oakbank Crannog is considered by Dr. Dixon to have originated as a :

'free-standing timber framework supporting a living platform on which was probably a round house, surrounded by a walkway and probably with a gangway to the shore' (Dixon, 1984b, 264).

As time progressed the supporting timbers weakened and had to be replaced and material built up underneath the platform until eventually the bulk of the dwelling platform was resting on a: 'mass of organic material' (op cit., 255).

The site was built on a silt shelf that extends away from the shore for about 50 metres. The silt shelf is terminated at the shoreward side by a boulder ridge that rises quickly and is an extension of the lake edge boulder material. On the other side of the crannog, to the south, away from the shore, the gently dipping incline of the loch bed is abruptly terminated as the silt drops steeply away. This steep wall of silt levels out periodically until the bottom of the loch is reached at a little over 100 meters.

Before excavation Oakbank Crannog consisted of a large oval mound of boulders, approximately 25 x 20m at its widest points. Physically associated with this mound was a smaller one, to the west, approximately 7m in diameter. The plan form and section of the original mound are shown in figure 5.1.

The boulders that cover the Oakbank site have been categorised into two groups: a 3m wide band around the periphery of the mounds and a layer, sometimes only one stone deep, capping the top of the site (Dixon,1984b,194). It might be argued that the lower band represented stones that were placed to help protect the piles from water action. However, it is clear from excavation that this lower material overlies organic layers and eroded pile tops. Thus, Dixon concludes that:

'it may be reasonably argued that the first phases of construction of Oakbank Crannog involved a free-standing timber structure without boulders around the foundations'(op. cit., 196)

The precise stage at which the boulders were added to the site and the role that they played is still a matter of much debate (Dixon,1984b,194-197; Morrison,1985,37-42; Crone,1988,47 & fig.10). The present study has little to add to this debate and this feature of crannog structure remains an enigma.

While the reason for the addition of the boulders is not clear it can be argued that the capping of boulders is one of the principal reasons for the physical protection of the underlying organic material at Oakbank. The crannog is located at the end of the longest reach on the Loch and when strong winds occur high waves are generated. If the boulders were not present it might be envisaged that only those parts of a crannog protected by the loch bed silts would survive. In essence this would be the pile tips that would leave such structures difficult to identify. Indeed, the last few seasons at Oakbank have revealed off-site constructions partially hidden by silt. The use of signatures in these situations to associate off-site structures with their 'parent' crannog or indeed to help identify crannogs without an organic matrix may prove to be a valuable aid.

When the boulders were removed, from the upper parts of the site, a layer of smaller stones overlying a thin layer of grit and silt was encountered. Removal of the small stones and grit revealed the top of a thick organic deposit within which uprights and horizontal timbers were embedded (Dixon,1984b,194). The organic deposits of the site rest directly on the silt of the loch bed. Some of the piling penetrates into the loch bed silts while the points of others reach only part way through the organic deposits. This feature has been used by Dixon to suggest different phases of building (see below and Dixon,1989,48)

The areas excavated to date are shown in figure 5.2. All areas, with exception of area A3, still have a good depth of organic material to be excavated. The excavation of A3 allowed for the drawing of two sections, figure 5.3. illustrates one of these sections. The sections demonstrate quite substantial structure even quite close to loch bed level. The depth of organic material on the shoreward side of the site is approximately 1m but it deepens to a maximum of about 3m as the loch bed slopes away from the shore.

All organic material below the boulder layer persists with the exception of bone that is virtually destroyed by the somewhat acidic environment (Dixon,1989,51-52). When the structure was inhabited building repairs were quite clearly undertaken without removing older

uprights. As a result a confusing array of piles survives throughout all areas of the main mound.

Many of the piles found on the crannog are not upright. On previous crannog investigations this has been suggested to be a deliberate policy at the time of driving to resist lateral pressure (Burns Begg, 1888, 122). However, at Oakbank many of the piles are leaning away from the centre of the crannog and thus the collapse of the main structure and pressure of the surrounding material would appear to be the most likely reason for their current resting position.

The shifting of the loch bed silts will also have caused movement of piles from their original position. That such movement can cause shifts within pile arrangements is clear on some other sites. At the site of Cortaillod-Est, Lake Neuchâtel, Switzerland, for example, the house structures clearly demonstrate the distortion of ground plans as a result of solifluction (Arnold, 1986, 80 fig. 82). At Oakbank it is possible that the movement of silt was periodically more violent than that encountered at Neuchâtel. The steep drop-off at the edge of the silt shelf at Oakbank may occasionally have become unstable leading to major structural warping of the site. The extreme angles of rest of some of the piles might attest to such events.

The movement of piles from their original driven position can make the identification of individual structures of particular building phases difficult. In this regard it is hoped that the current project may demonstrate the manner in which signature links between piles may begin to tease out patterns amongst an otherwise confused array of material.

5.3.1. Principal internal structures

Some 25 internal structures have so far also been suggested by Dr. Dixon for the excavated areas. The movement of piling and the periodic repairs at the site make such definition difficult and thus the features suggested mostly remain tentative. They are identified by either post alignments or horizontal structure. Dr. Dixon's original plan of these features is reproduced in figure 5.4.

The features proposed are considered to form part of the crannogs main entrance structure. Features 3 and 4 are conjectured to be part of a door structure possibly the two door-posts (Dixon,1984b, appendix B). Features such as F1, F2, F5, and F6 are seen as parts of the outer walling while F8-F10 are considered to be elements providing support to: 'radial timber on which smaller longitudinals lay to give a walking surface' (op. cit.,2). Features F11 - F14 may also have functioned in the latter fashion.

Of all the features proposed the floor areas are the most clearly defined (Dixon,1984b,appendix B,F17 and F24). The form of at least one of these floor layers is well shown in the plans for areas B3 and C2 (see fig 5.4). Remnants of this structure may also just be present in areas B4 and D4. The floor is formed from unworked roundwood lengths laid parallel to each other. The manner in which this structure was originally attached to the rest of the building is not clear from the material so far excavated.

Seemingly related to the floor features, although not physically attached, is a very clear alignment of narrow diameter posts (F7). These are too small for major structural support but can be imagined as forming an internal division or perhaps supporting part of the external wall.

5.3.2. Principal external structures

In addition to the material of the two mounds there are three main features found within the loch bed silts surrounding the site. These are the causeway structure, the extension feature, and the row of off-site piles.

The causeway structure consists of 40 oak posts leading away from area A3 to the edge of the boulder shelf that defines the start of the shore line (fig.5.1). That these posts supported a gangway into shore is clear. However, it is not certain whether the structure continued beyond the line of the boulder shelf. It is also uncertain whether this feature was part of the primary construction of the site although this is extremely likely.

The extension feature is a roughly semicircular arrangement of piles that run around the outside of what was the smaller of the two stone mounds at Oakbank. Part of this structure has a clear pattern of paired posts, in a double row, but closer to the main mound, at either end of the semicircle, this pattern is no longer clear. The extension feature is the most heavily sampled of all the features at Oakbank both for its tool marks and dendrochronologically.

The posts in the extension structure often had light coverings of silt camouflaging their tops. This has sometimes made relocation of the piles difficult even when the diver was familiar with the configuration of the feature. Consequently, if other structures exist beneath the silts around the crannog they may only be found by chance or with some form of remote sensing.

In 1988 two piles were found by chance some distance from the site. Subsequent silt removal in the area around these piles has slowly revealed a row of twelve that run west at a right angle to the causeway structure; significantly this structure does not follow the natural line of the shore. The relationship suggests that the builders of the off-site feature were constructing it with the causeway in view. Furthermore, recent radiocarbon dates have clearly suggested that this feature is contemporary with at least part of the main crannog (see section 5.4.2). The twelfth member of this group was found in 1993 and there is every likelihood that more will be located in future seasons.

The function of the off-site alignment is not clear at present but it is noteworthy that a similar situation was observed during the superficial investigation of a crannog in Lochleven during the last century. About mid way along the causeway structure of the Lochleven crannog they: 'came upon traces of a transverse row of piles' (Burns Begg, 1888, 123). These piles seem to have been of a similar form to those at Oakbank, being much smaller than the piles found in the causeway.

Additional structure has also been located on the side of the crannog away from the shore. The tops of the piles in this area occur some 50-70 cm below what was previously thought to

be undisturbed loch bed silts. At present only a small area of this newly discovered material has been exposed and its full extent and function remains uncertain. In the current thesis this material will be collectively known as the 'deep pile group'. This material demonstrates that substantial wooden structure is to be found at Oakbank beyond the limits defined by the stone covering to the site.

5.3.3. Stratigraphy.

The Oakbank site is a mass of organic material surrounding a large number of piles and stakes; this material initially gave the impression of being one heterogeneous layer (Dixon,1984b,205). Subsequent excavation has revealed a complex array of materials in a number of compacted layers. However, these strata in many cases: 'blended regularly one into another' (op.cit.,206), indeed: 'no single stratified deposit could be followed for a significant distance in any direction' (op.cit.).

The complexity of these deposits is probably the direct result of the excellence of preservation on the site. What is being observed in many cases are, arguably, short lived depositional occurrences resulting from single events, possibly the laying of new bedding material or the mucking out of animals. Not all events will survive in the deposits, inhabitants occasionally clearing the house and periodic erosion of the deposits will confuse the situation. Woodworking debris is also found in high concentrations on certain parts of the site. It is possible that the sampling of these woodchips for tool marks and subsequent analysis of signature connections will indicate the short lived nature of some of the Oakbank deposits.

The stratigraphy at Oakbank clearly demonstrates that parts of the site were strengthened or rebuilt over the life of the site. Initial excavations at Oakbank indicated: 'that at least four building phases occurred' (Dixon, 1984b, 260) and more recently it has been suggested that: 'there may have been as many as five or six major stages of construction'(Dixon,1989,47-48).

The initial phase of site construction is represented by large uprights that have been driven deeply into the loch bed silts, as in the case of pile 103 (Radiocarbon determination GU-

1323). These timbers represent the major structural uprights that supported the initial free-standing structure. The last surviving phase on the site is represented by smaller stakes found at the top of the organic material driven to a depth of only 10-20 cm (Radiocarbon determination GU-1463/GU-1464). The final phase has been conjectured to follow on from a period of abandonment during which time layers of silt and gravel accumulated (Dixon,1984a,218). By this stage the site may no longer have been free-standing and the structure could have rested directly on the underlying mass of material. Phases in-between these two have been inferred from piles driven into the organic deposits to varying depths (Dixon,1984b,261). The number and nature of intervening phases will only become clear when more of the structure has been excavated.

In addition to the piling, the floor features (F17 & F24) clearly represent coherent phases of building. However, the exact relationship between the different phases indicated by the level of pile points and those indicated by horizontal material is mostly unclear. The relationship between the external features, discussed above, and the main site stratigraphy, is also not clear. It is, however, possible that signature matches will relate woodworking on these features to material within the main mound. This might include a link with a woodchip that would neatly tie unstratified piles to the layering of the site.

While the site stratigraphy indicates that Oakbank has been repaired and adapted over time it is not yet possible to determine the absolute rate of build up. The following sections examine some of the problems involved in producing an absolute chronology for the site.

5.4. The date of the site

The general chronological position of much of Oakbank Crannog is well fixed between 800 and 300 BC. Its occupants may well have experienced the technological shift from bronze to iron using (Dixon,1981b,346). The finer resolution of its chronological position is, however,

more difficult to determine. The following highlights some of the main problems and provides the background for many of the comments made in chapter 15.

5.4.1. Radiocarbon determinations

The increasing availability of radiocarbon dates in the late 1960's generated much optimism for the chronological resolution of the first millennium BC in Scotland (MacKie,1969). This optimism turned sour once it was realised that there was a major calibration problem for much of this period creating what has been termed as: 'a catastrophe for Late Bronze Age/Iron Age archaeology' (Baillie & Pilcher,1983,58). The dates from Oakbank illustrate many of the basic problems.

Four radiocarbon determinations were conducted on the Oakbank material during Dr.Dixon's original assessment of the site and were as follows:

- **OB1** - 2410±60 (GU-1325)
- **OB2** - 2545±55 (GU-1323)
- **OB3** - 2360±60 (GU-1463)
- **OB4** - 2405±60 (GU-1464)

The first of these dates was from an oak pile at the junction between the main mound and the southern end of the extension feature. Sample OB2 was from an in-situ pile considered to be part of the primary construction (No.103). Samples OB3 and OB4 were from two small alder stakes imbedded into the upper layers of the organic material on the main mound. These dates thus encompass the earliest and latest surviving material on the site.

During the current project five additional radiocarbon assessments were conducted resulting in the following dates:

- **OB5** - 2490±50 (GU-3468)
- **OB6** - 2560±50 (GU-3469)
- **OB7** - 2510±50 (GU-3470)
- **OB8** - 2490±50 (GU-3471)
- **OB9** - 2450±50 (GU-3472)

These were conducted to assess the date of the features examined during this project that were found outside the material of the main mound (see above). Sample OB5 was from the causeway (Pile C18), OB6 and OB7 (Piles 1744 and 1743) from the deep pile group and OB8 and OB9 (two samples from pile 1748) represented the off-site pile alignment. It is clear from this set of dates that all these features are broadly contemporary with the main mound. This was particularly useful in confirming the association of the off-site post alignment with the general date of the main site.

Finer resolution of the chronology of the site's construction is still, however, problematical. Once calibrated these dates gave a wide spread of options as they fall within a problematical area of the calibration curve. The flattening of the calibration curve between 800 and 400 BC has the effect of broadening the range of possible true dates signified by a given radiocarbon determination. The broad date range that results from calibration within this period is well illustrated for the value given for sample OB2, pile 103. Using the error bracket of the radiocarbon date at the one sigma level, i.e. 50 years either side of the mean, gives a calibrated range of dates cal BC 797-757 and cal BC 680-546 (fig.5.5; Stuiver & Reimer,1993). At the two sigma level, using 100 years either side of the mean, even broader ranges are produced: cal BC 809 - 484 or cal BC 446 - 422.

In calibrating the date for sample OB2 the standard intercept method has been used (Bowman,1990,fig.19). In other words only the mean line and standard deviation lines have been considered. This method does not fully utilise the probabilistic qualities of the normal distribution. Methods are available, however, that utilise this factor and produce some idea of the most likely date range for a particular determination (op.cit.,fig.20). In the case of OB2 at the one sigma level (68.3% of the original distribution) there is a much higher chance that the true date lies within the range cal BC 680 - 550 (73%) than it does in the range 800 - 760 (27%). Figure 5.5 produces a simplified bar representation of this method for all the dates from the site.

While there are problems with calibrating the dates for this period, plotting the probabilistic calibration appears to show an interesting pattern when the stratigraphy is also considered. At its most simple it can be clearly seen that the small stakes set into the very top of the site are clearly the latest material while pile 103, a large oak set into the silt below the organic material of area B3, and pile 1744, an alder pile within the deep group, are amongst the dates most likely to be early. This pattern is not perhaps surprising. However, when the other dated material is considered some more subtle pattern seems to appear.

It can be argued that the data splits neatly into two. The first, the earliest, includes, in addition to piles 103 and 1744 described above, a member of the off-site pile group (pile 1748) and one of the 40 oak piles that make up the causeway (C18). The second, the latest, includes, in addition to the stake points described above, the pile from the junction between the extension feature and the main mound, and pile 1743, a member of the deep pile group.

The occurrence of a pile from the deep group in both the early and later data sets might appear odd given their stratigraphical position. However, it will be shown later in this thesis, through signature matching, that the burial of the deep group has little to do with the time at which the piles were driven. Indeed it is likely that within the deep group there is more than one phase of building and the burial of the piles occurs quite late in the occupation of the crannog or even shortly after its abandonment (see chapter 13).

In essence the dates seem to suggest an early phase of construction that includes the building of the causeway, a possible fence line or revetment, and the placement of major structural uprights to support the platform. This initial phase probably took place sometime in the late fifth to early sixth century. The latest phase surviving on the site included major structural repair/rebuilding work as well as some minor alterations/repairs to the internal divisions of the site. The central part of the site by this stage appears to have been resting on the accumulated mass of organic material that now forms the main mound. This final phase occurs somewhere between the mid fourth to mid fifth century BC.

The printout of the calibrated Oakbank dates from the Stuiver and Pearson calibration program is included as appendix A.

5.4.2. Dendrochronological determinations

The problems of calibrating the radiocarbon determinations make it virtually impossible to build up a clear picture of site building and repair. For a site with so much wooden material surviving dendrochronology is a logical place to look for fine chronological resolution. Some work has been conducted for the site as part of a PhD thesis (Crone, 1988). Dr. Crone's study concentrated on an examination of alder timbers from the site. As this species make up over 70% of all the timber so far found on the site its study was essential for any long-term dendrochronological examination of the crannog. Alder is not the usual species for dendrochronology. The impressive absolute chronologies that have been built up over the last few years for some areas are based mostly on Oak material or pine timbers (e.g. Becker, 1993).

The manner in which alder grows makes it a difficult wood to work with dendrochronologically. Clear matches between a number of timbers, possibly from different stands, require a wood, such as oak, that has a broadly similar response to the general climate of the area. Alder can be highly affected by local micro climatic conditions, in fact when under stress it need not put on a growth ring at all. Missing rings can cause problems for the dendrochronologist as it puts the sequence of ring widths out of phase when comparing two timbers.

The fast growing nature of alder and its sensitivity to the local micro climate can also lead to erratic ring formation. To check for this possibility more than one curve is produced for each sample along different radii. In some cases it may not even be possible to match up different radii from the same sample.

The problems associated with alder make it unlikely that it will ever be used for more than constructing relative chronologies on a site. Dr. Crone has produced relative chronology for the site based on a sample of 250 timbers. In fact two versions of the chronology were produced, based on different approaches to the matching procedure. The dendrochronological work is discussed fully in chapter 15.

5.4.3. Typological determinations

The conventional typological studies of pottery and metalwork on site are obviated by the poor quality and infrequency of the former and almost complete absence of the latter. Furthermore, pottery, in these and other northern areas, has been considered as: 'too insensitive to be of much value as a cultural or chronological indicator' (Megaw & Simpson, 1984, 449). It has been remarked that there is a gradual cessation of pottery as a: 'significant element of material culture' (Cunliffe, 1991, 54) in the Midlands, Wales and much of the North towards the end of the Bronze Age. A fact that contrasts sharply with the strong ceramic tradition of the extreme northern areas of Scotland that flourished well into the Iron Age (op. cit.).

The pottery at Oakbank does nothing to counter these comments being of extremely poor quality and apparently little diagnostic value (Dixon, 1984a, lower plate; Dixon, 1984b, plate 54). Indeed the note of caution sounded by Jobey when examining the pottery from the Iron Age settlement at Burradon can equally well apply to the Oakbank material:

'the forms are so basic and unsophisticated, and the pottery so crude, that quoting parallels may not only be useless but even dangerous' (Jobey, 1970, 73-74)

In addition to the pottery found on Oakbank Crannog a small jet ring has been discovered. These associations have been noted to occur across a variety of sites over a wide area of Scotland although this is not shown to be a particularly sensitive chronological indicator (MacKie, 1969, 19-20). The significance of these similarities in terms of the current assessment is thus very difficult to determine.

Despite the apparent undiagnostic nature of the pottery and the pessimism of Jobey it has been argued that similar pottery within the Tyne-Forth province may yield to a degree of typological analysis (Cool,1982,92). These distinctions may be relevant to the Oakbank material especially given reappraisals of Piggott's original sub-divisions of northern Britain (Piggott S.,1966). It may be considered, for example, that there is some evidence for: 'cultural continuum north and south of the Forth' (Harding,1982b,1-2).

The pottery from Oakbank seems to broadly fit with Cool's Type I; it has large grit temper in excess of 1cm long, a body width of over 2 cm (over 3 cm in the case of Acc.213), clear evidence of grass temper, a variable fabric colour and some evidence of inturned rims (Cool,1982,93-94). Cool's assessment concerns material from the excavations at Broxmouth, Douglassmuir, and she places these pottery characteristics within her middle assemblage, between 450 BC and 250 BC. However, in the absence of other artifact types from Oakbank defined as part of her middle assemblage it would be unwise to draw too many conclusions from this parallel.

That Cool's early phase is regarded as aceramic may bolster the argument for Oakbank's mid-late first millennium position. However, it is also true that saddle querns and crudely made stone bowls are regarded by her as early at least within a south east Scottish context. Both of these artifact types are found within the upper layers at Oakbank and further suggest caution in making simplistic parallels.

Metalwork has until very recently been completely absent from the site. In the summer of 1992, however, an iron spear/knife point was found. Unfortunately, this was located out of context although the likelihood is that it came from within the organic matrix at the edge of A2. This piece is very similar to that found at Meare Village East (Coles,J.M.,1987a,find no.142,fig.3.50). It is also very similar to a find from the Iron Age Hillfort of Midsummer Hill found in a context dated to around 200 BC (Stanford,1981,124,fig.58 no.2). However, the dangers of using an individual find to make general statements about the chronological

position of a site have been highlighted on a number of occasions. Of particular relevance in this situation was the excavation of Milton Loch where a find of a bronze loop enamelled in red and yellow was said to have:

'fixed the date of the crannog to approximately the 2nd century AD' (Piggott, C.M., 1952-53, 139).

Subsequent analysis, however, demonstrated that this site had a much earlier constructional basis (Guido, 1974, 54-55) possibly close to that of Oakbank. The iron find is discussed more fully in section 7.2.2.

Of the material of which there is an abundance, namely wood, there has been too little work and more importantly too few sites fully excavated to establish exactly how useful an indicator certain wooden artifacts will be. The validity of using wooden material within typochronological schemes has in any case been questioned, largely as a result of the incomplete nature of the sample set (Heal, 1982, 98).

The abundance of wooden material within crannog sites alone may, however, allow such typologies to be built up as more are excavated. A recent article by Caroline Earwood discusses the artifacts from the sixth/eighth century AD Loch Glashan crannog, Mid Argyll, and demonstrates the diversity of forms that can be present in wood; that typological frameworks can be constructed for wooden material is strongly suggested by the evident parallels with pottery from the site (Earwood, 1990, 85, illus.7). The typological significance of wooden material has been further discussed in relation to parallels with metalwork (Earwood, 1989/1990). This work has led to a confident prediction for the future of :

' a secure chronological framework for wooden vessels not found in stratigraphic contexts' (op. cit., 44).

Although there are grounds for a degree of optimism in this regard it has to be said that at present the woodworking at Oakbank seems to be too basic to be a sensitive chronological indicator.



Technological innovations in woodworking may give a sense of a site's age; the presence of certain types of toolmarks could provide useful clues. However, here again these may only be crude indicators and rely on the confidence placed on the evidence for the first occurrence of a particular technique. Furthermore, techniques may not change in any significant manner from one period to the next.

The woodworking technology at Oakbank appears solid but basic. One or two artifacts show greater skill, as the find of one stave from a small container exemplifies. However, such techniques are known from other earlier sites such as the stave found at the Bronze Age site of Cauldicot, Monmouthshire (Nayling pers. comm.) and the collection of Middle Bronze Age stave fragments from the Wilsford Shaft, Wiltshire (Ashbee, Bell & Proudfoot, 1989, 51). Furthermore, the use of a particular technique may slip in and out of vogue over time. The material from the sixth-eighth century AD site in Loch Glashan contains no stave material at all, a situation that contrasts markedly with contemporary sites in Ireland (Earwood, 1990, 92-93).

No turned material has yet been found on the site. The one object that could easily have been produced by turning, the circular plate, is clearly carved. The rest of the containers found on the site are oblong or oval. The discovery of turned material may not in any case be a particularly good chronological indicator. It is uncertain when the use of the pole lathe began in Britain although its use on wood by the Iron Age is well established, at least in southern England (Gray and Bulleid, 1953, 278, fig. 75). The mention of a finely turned bowl in the Wilsford shaft may suggest a much earlier use on wood, but its subsequent loss prevents positive identification (Ashbee, 1963, 118).

5.4.4. Summary of dating issues

The result of a combination of problems makes the precise date range of the site's occupation uncertain. Consequently, it is unclear whether the inhabitants existed during a time when bronze was the primary metal used for edge tools or whether iron was playing a

significant role in the life of the crannog dwellers. In many respects this question is one that might conceivably be addressed by examination of the woodworking attributes of the site. The issue of linking tool typology and material to the work done by an individual tool is addressed in chapter 15.

CHAPTER 6

Wooden material - Species use and form.

The following chapter gives a summary of the wooden material found at Oakbank Crannog; the species used and the material uncovered.

6.1. Species use

In early reports of Scottish crannogs, oak (*Quercus* sp.) is the most frequently mentioned species of wood. Such observations may not represent a true picture of species use, as oak is the one wood that is easily recognisable; from the blackening of the heartwood and its hardness. Because of these two characteristics, waterlogged oak piles tend to stand proud of the surrounding deposits and may thus be more readily identified.

Modern examinations have shown that crannog builders used a variety of species, the proportions of which can differ quite significantly from one site to the next (Crone, 1988, 30-31). At Oakbank Crannog the most commonly used wood is alder (*alnus* sp.) (fig. 6.1). The majority of the piling so far examined is formed from trunk wood of this species. Alder is also found to form a high proportion of the horizontal timbers, some 51%; this includes the large morticed timber discussed below. The same is also true of many of the domestic or portable artifacts so far found, the butter dish, 'canoe paddle' and plate all being made from alder (see below).

Such species use was apparently reflected in the excavation of Milton Loch I crannog where the horizontal and piling elements examined were all of alder (Piggott, 1952-53, 152). However, recent examination has suggested that oak was also a significant element of the construction on this site (Dixon pers. comm.). By contrast the excavation of the crannog in Eaderloch demonstrated structural timbers formed primarily from birch (*Betula* sp.) and pine (*Pinus* sp.) (Ritchie, 1942, 72). Birch is rarely used in the structure at Oakbank and pine has so far not been encountered as piling or horizontal elements.

The abundance of alder reflects the ideal growth conditions around the loch side for this water loving species (Mitchell,1989,128). It is noteworthy that the local village place name, Fearnan, is derived from the Gaelic word for alder - fearna (Rackham,1980,305). In addition to its abundance it is also a good constructional choice being well known for its durability in permanently waterlogged situations, a fact well documented from early in written records (Vitruvius, trans. Hickey-Morgan,1961,61).

Although alder predominates amongst the piling at Oakbank, it is mostly oak used as uprights in the causeway (Dixon,1984b,233). Oak is the next most abundant wood used for piling. Elm (*Ulmus* sp.) and willow (*Salix* sp.) are the only other two species occasionally encountered as major structural uprights (2% and 3% respectively).

The use of other species for particular functions is observed. The hurdle work found in area A2 in 1991 is formed, not surprisingly, of hazel (*Corylus avellana*) as are a number of the smaller points and stakes. The use of Scots pine (*Pinus sylvestris*) is commonly found as burnt tapers, its resinous nature allowing for a long slow burn (see comments by Cave-Brown,1991). The identification of a small Scots pine woodchip does, however, suggest that other uses might be expected.

Species use on the site is reflected by the cores taken for pollen investigation although birch was a far more common feature of the woodland than its use would suggest. The tree and shrub pollen from the core are dominated by hazel, alder and birch in that order, with a background representation of oak and elm (Scaiffe in Dixon,1984b, appendix E). It is likely that alder is over represented in the pollen core, given its tendency to grow in the wet environment prevailing along the shore of Loch Tay. The extent of oak and elm woodland is, therefore, hard to assess but is considered to be a significant element on the drier soils away from the loch shore (op. cit.).

Of the tree and shrub pollen recorded by Scaiffe four species are marked as present that have not yet been identified as being used on site. These are lime (*Tilia* sp.), *Populus* sp., yew (*Taxus* sp.), and juniper (*Juniperus* sp.).

6.2. Wooden artifacts.

Wooden material from a site can be broadly divided into three groups:

- Structural artifacts
- Domestic or Portable artifacts
- Waste material

Structural artifacts encompass all wooden material that has direct association with the fixed structural elements of the crannog. Structural artifacts can be neatly divided into four main classifications, from the bottom to the top of the structure:

- In-situ piles and stakes
- Horizontal material
- Internal divisions
- Roofing elements

At Oakbank Crannog elements of upper structure have been exposed to damage, erosion or loss. Consequently, wooden roofing structure has not yet been clearly identified. Internal divisions have only survived as either the ends of stakes (e.g. feature 7 see chapter 5) or more rarely as collapsed wattle work such as was found in area A2.

6.2.1. Structural artifacts - Piles & Stakes.

In an article surveying the nature of wood from various projects in Europe and America, Professor J.M. Coles makes the following comment:

'It would appear that the excavations underwater of large prehistoric sites tend to yield fewer structural pieces than do comparable sites in peat, a reflection of the preservation quality of water, hence less need to lift material, the greater expense of underwater work, and perhaps the poorer preservation of many piles and posts underwater.' (1988,8)

It is certainly true that at Oakbank the upper structure of the building is poorly preserved if at all. However, the ends of the piles and posts are very well preserved. Furthermore, even on the best of waterlogged occupation sites, of whatever nature, the preservation of complete piles and upper structure is not common (Arnold,1982,111). At the site of Flag Fen, for example, only two possibly complete uprights have been found (Taylor,1992,fig.5 & 7). Furthermore, their complete survival was a result of never having been used and having lain horizontally. The discovery of these timbers did, however, lead to the recognition of other, more fragmentary, elements of the upper parts of constructional piling amongst the rest of the material.

At Oakbank there is not yet any definite clues as to the nature of the upper sections of the piles or to the manner in which they were attached to the platform. The finding of an unused upright, or at least its upper section, is not, however, beyond the realms of possibility. During the 1991 season a pile point was found lying on its side in area C1 (Timber 1582). The pointed section was in good condition and there was evidence of it having been reused as a chopping block. Unfortunately, the find was high up in the stratigraphy and the upper part demonstrates that at some time in antiquity the deposit was eroded away, destroying what may have remained of the rest of the timber.

6.2.1.1. Pile production and form.

All the uprights so far found at Oakbank with one exception are fashioned from complete roundwood, often with the bark still attached, using an axe (fig.6.2; Plate 6.1).

Piling can be made from the split segments of larger trees such as at the Late Bronze Age site of Auvernier-Nord, Lake Neuchâtel, Switzerland (Arnold,1982,122, fig.6.8). Only one pile from the Oakbank, which is of half split oak (see Crone & Barber,1981, primary conversion B) shows the use of such reduction in pile manufacture. The availability of suitably sized trees, predominantly alder, around Loch Tay would seem to have largely obviated the need for the conversion of larger timbers for piling.

At Oakbank Crannog the working of the piles to a point falls into two main patterns, concentric and eccentric. In the former case the timber is worked equally all round leaving a point symmetrical to the heartwood. In the latter case working is conducted in such a manner as to leave sapwood down one side, in some instances almost to the very tip (fig.6.2). On the basis of the piles so far examined the eccentric form appears to be more prevalent. Indeed during the experimental working of pile points it was found that the most convenient method was to work one half of the tree more than the other.

It can be seen that the piles extracted from the causeway and some of the larger primary uprights are concentrically worked while the extension piles and the off-site group are eccentric. The difference may be species related rather than connected with a particular phase of building. The cutting of a pile point eccentrically requires marginally less effort, in terms of having to stop to rotate the piece, and is convenient with wood species that have a basically homogeneous structure, such as alder. In cutting mature oak, however, it might be suggested that the less of the harder heartwood that has to be cut away the better. This can be achieved by chopping all the way round increasing the amount of sapwood removal and reducing the need to cut right across the heartwood. This also has the advantage of producing a pile tip that is formed entirely of the harder central material.

Some stake points have also been examined during this project. These are smaller roundwood uprights and are not directly related to major structural support. The cutting of the smaller points is different from that encountered on the piling. Two types of cut point have been identified on the site; chisel-ended and wedge-ended. Chisel-ended points are those cut on one side of the wood only; wedge-ended points, by contrast, have been cut from both sides to form a 'V' shaped end. These terms were coined during the Somerset Levels Project to classify the large number of stake points found along the many trackways investigated (Coles & Orme, 1985, 26-27). The classification has also been used and extended during the examination of the woodworking on prehistoric trackways, in the raised bogs of Co. Longford, Ireland (O'Sullivan, 1991, 58-59). In addition, O'Sullivan attempted to use the angle that the

cut surfaces made to the long axis of the timber to distinguish between woodworking from sites of different periods. Unfortunately the number of stake points so far recorded at Oakbank is too minimal to make meaningful comparisons with either the Irish or the Levels material.

6.2.1.2. Pile driving and tree orientation

During initial assessment of the piling from Oakbank Crannog it was hoped that marks would be found on the timber that gave some clue as to the method that was used to drive the piles into the loch bed. However, no such marks have been found. Indeed, considering the coarse material through which the timbers have been driven it is remarkable that the fine striations of the signatures have survived the driving process.

The cutting of piles to a point seems to have been quite a consistent process judging by the marks remaining on the timbers. In all the cases so far examined the piles appear to have been cut with the points contrary to the direction of the growth of the tree - in other words the timber when in position was the same way up as it had been when alive. This is an interesting point and contrasts with the piles found at Stoneykirk in Wigtownshire. In 1903 Ludovic Maclellan Mann commented about these piles that:

'One of the most remarkable facts disclosed was that, in all cases where the direction of the growth of the tree or branch was recognised, and this was detected in nearly every instance, the piles had been placed upside down, or contrary to the direction in which the timbers had grown. In other words, the top end of the branch had been pointed and dressed, and had been placed downwards in the clay. Now it is well understood that stakes inserted in the ground against the line of growth or "cap down", to use the technical term, last longer than those placed in the direction in which the timber has grown.'(1903,378-379).

It is argued that the piles survive longer when driven in this orientation. It can also be suggested that it prevents any regeneration of growth after driving. The use of timbers 'cap down' in pile constructions has also been noted on those found on the Late Bronze Age structures at Cauldicot, Monmouthshire (Nayling pers. comm.).

At first it might be argued that the tendency of the Oakbank builders to point their timbers contrary to the growth direction would on occasion generate more work particularly when dealing with the lower parts of the tree. With the increased thickness of the girth a great deal more wood would be required to be removed. However, it can be suggested that once the rest of the structure is taken into consideration there may well have been advantages in cutting their points in this manner. In particular piles fashioned this way would leave available a number of potentially useful side branches to which upper structure could be attached. Furthermore, as the platform had to be supported well above the water to allow for variations in loch level over the year and during storms, very tall uprights would be required. It is possible that some of the timbers would be in excess of 8 or 9 metres. Given the length of the timbers required it would, perhaps, have made sense to have had as much of the thicker part of the trunk at the lower end of the pile.

6.2.2. Structural artifacts - Horizontals

Much of the horizontal material so far found on the site is in the form of roundwood lengths and in some cases clearly forming part of a collapsed floor structure (See chapter 6 & Dixon, 1984b, 254-255). These have not yet shown any evidence of significant working.

Parts of jointed timbers have been found and a number of pieces retain mortice hole fragments. One of the largest demonstrably worked horizontal timbers found at Oakbank is a piece made from alder some 4 metres long with three mortice holes at either end and 13 peg holes down its centre (timber 1531; fig.6.3). Although eroded it has been clearly produced by splitting a piece of roundwood in two (Crone and Barber, 1981, primary conversion B). Splitting is relatively easily achieved when dealing with well-grown oak. The well-defined rays of an oak tree provide clear lines along which the material can be wedged apart. Timber 1531 is, however, formed from an alder tree and the splitting process must have been more problematical. Alder rays are not as well defined as those of oak and they tend to twist down the long axis of the tree. It is likely that the flat side of this timber received a certain amount

of surface dressing but the marks no longer remain. The other side of the timber is mostly unworked sapwood with small patches of bark still adhering to its surface.

Timber 1531 is clearly part of a relatively elaborate construction but it is difficult at present to determine exactly how it fitted into the structure of the crannog. The pegs are possibly the eroded ends of wattle work sails; the mortice holes would receive the ends of supporting uprights. Its position on the site would suggest that it had a functional role as part of a doorway structure. In this regard it is interesting to note the plan of Milton Loch I Crannog, so often used as an illustration when Scottish crannogs are mentioned (Piggott, 1952-53, fig. 7). Examination of this plan reveals a large horizontal split timber with a series of four mortice holes at either end positioned close to what has been conjectured to be the entrance to the site. However, no detailed comment is made about this piece and the central portion is hidden on the plan by overlying horizontals.

Despite the functional complexity of timber 1531 it is interesting that, like so many of the artifacts found on site, it has had minimal finishing. The use of timbers with bark still present is a common feature of much of the structure and appears to indicate a rather pragmatic approach to construction.

The morticed timber overlies an area of intact wattle work that may well originally have been attached to it. This material is fashioned from hazel and along with a very small fragment of daub probably represents the only surviving evidence for the walling of the crannog yet found.

6.2.3. Domestic or Portable artifacts

Domestic or portable artifacts at Oakbank Crannog have included the remains of four wooden containers, a wooden spoon (destroyed during conservation), a plate, peg, whistle and a number of more curious items the function of which remains conjectural.

An oval bowl, found in 1990, is one of the largest containers so far uncovered; it was carved from a single piece of wood and was broken after being discarded when a pile was driven through its base. Because the pile pierced the centre of this object so neatly it is tempting to suggest that the bowl was deliberately placed.

Two oblong vessels have also been found. One of these has only parts of the sides and ends surviving with a small area of its base. The other is perhaps the most interesting of all the containers so far found at Oakbank. It represents one end of an oblong vessel, with evidence of three holes through its base (fig.6.4). It was fashioned from a split piece of alder, the length of the vessel following the long axis of the timber. The bottom of this container preserved the remains of butter and the object is consequently referred to as the butter dish. The butter dish is also the only vessel found at Oakbank to retain evidence of tool-marks (see chapter 7). Its form, including the holes in its base, is reflected in a find described by Munro from Lochlee crannog (Munro,1882,93;Section 3.1.1. this thesis).

A single stave from a small circular container has also been found (fig.6.5). Its curvature has enabled Dr. Dixon to reconstruct its original dimensions; suggesting a container that originally had 6 staves and which would have had a capacity of approximately 1.5 pints (Dixon,1989,50-51).

A neatly carved shallow wooden plate has also been found (plate 6.2). It is circular in form, some 18 cm in diameter and about 3cm deep. It is clearly carved, rather than turned, but like most of the portable artifacts from the site no longer retains any clear tool-mark indications.

All the examples of worked wooden domestic artifacts so far found have shown no evidence of carved ornamentation. This is not perhaps surprising as decorated containers such as those found at Glastonbury (Earwood,1988) are the archaeological exception rather than the rule (Evans,1989,183-187).

Some of the smaller items have clear functional roles. The hazel peg, for example, is clearly designed to provide an attachment for something that was applying force in one direction only, in a similar manner to those used to hold the guy ropes of a tent (Dixon,1989,51; fig.6.6). However, while the utilitarian nature of many of the wooden artifacts is apparent there are a number of finds that are not neatly placed in any particular category. Of particular note are a carved woodchip and a small circular piece with two lateral projections jointed into a carved twig (plates 6.3 - 6.4). The functions of these pieces remains obscure.

From a technological point of view all the wooden finds from Oakbank are neatly executed but do not require an extensive tool kit. All the pieces show a high degree of competence but little extra effort appears to have been expended in their production. In many cases, with the exception of the smaller objects discussed above, it seems that once the functional criteria had been fulfilled the object was finished.

6.2.4. Waste.

The stratigraphy of Oakbank Crannog is interspersed by patches of wood chips. Plate 6.5 shows one of the larger chips from the site. The working debris of carpentry is not a usual find around structures and it has been inferred for most sites: 'that much of the working was done in the woodland shortly after felling' (Coles,J.M.,et al.,1978,29). The finding of a large amount of debris at Oakbank does not preclude the general applicability of this theory.

It is still uncertain as to the amount of work represented in a particular deposit; even apparently quite limited woodworking can produce a surprising amount of debris. Experimental work conducted during the Somerset Levels Project demonstrated this very fact. During the Levels Project it was noted that:

'as many as 50 or more accurate chops with a stone or a bronze axe would produce a sharpened stake but the artifact would bear only 5 or 6 identifiable facets or axe scars, the others truncated or lost by the sequence of action' (Orme and Coles,1983,22).

These observations are borne out by work conducted during this project, where between 500 and 800 blows were required to produce a pile point upon which only some 100 facets remained.

A functional role for woodchip deposits on site may be suggested. The use of woodchips to consolidate uneven areas, for example, has been noted around building 1 of the Iron Age structures found at the Goldcliff site on the Severn Estuary (Bell,1991,13). However, there is not yet any evidence for such a functional role to be proposed for the material at Oakbank.

CHAPTER 7

The tool marks

In this chapter the nature of the tool mark evidence found at Oakbank Crannog is reviewed. The situations in which tool marks survive are examined in the light of the wooden artifacts introduced in the last chapter. From this examination the woodworking tool kit that was available to the Oakbank dwellers is suggested. The assessment of the tool kit is restricted to the functional types used rather than the absolute form of the tools. The extent to which the latter can be derived solely from tool mark information is more fully discussed in chapter 15.

7.1. Tool mark survival

The survival of tool marks on archaeological timber is dependant on a number of factors. These are related to the nature of the woodworking at the time of production, the uses to which the material was put, the manner in which the material was deposited and, finally, post depositional processes. These factors have been encapsulated by Taylor into a five fold categorisation of tool mark survival (Therkorn et al., 1984, 363-365) and can be summarised as follows:

- ❶ No tool mark survival despite obvious shaping, either as a consequence of careful final finishing of the piece or subsequent deterioration.
- ❷ Slight tool mark indications.
- ❸ Tool marks giving limited information - basic information about features such as the manner of shaping can be determined.
- ❹ Marks with full or partial tool outline.
- ❺ Tool marks with signatures.

The lack of tool marks on a timber may represent either careful finishing of a piece or erosion of the surface. Full signatures are most likely to survive on pieces that have been rapidly buried after manufacture and which do not require carefully finished surfaces.

7.1.1. Tool marks on piling.

All the piles so far extracted from the site were examined and cast if signatures were present. In addition as many of the piles within the excavated areas of the site as possible were assessed for signature survival. In a number of the areas the faceted surfaces of the piles were still too deeply buried to allow for the casting of tool marks (see chapters 9 & 10). Of the piles examined 130 were found to have faceted surfaces that could be cast. As well as the piling, 29 cut stakes also retained evidence of tooling.

Tool mark survival on the piles at Oakbank is, in general, excellent. Indeed, if such information is to be sought on wetland sites structural uprights are the most likely objects on which it is to be found. At Flag Fen, for example, over two-thirds of all tool marks so far found have come from the tips of uprights. This has been attributed by Taylor to the fact that: 'they are often freshly cut, just before being driven into the waterlogged ground' (Taylor, 1992, 486).

Signature survival on many of the piles at Oakbank is of a high quality. This contrasts with uprights so far examined at Flag Fen where few signatures have been found. A similar comment can be made about the Late Bronze Age wood from the site of Cauldicot, South Wales, where a very small proportion had signatures (Nayling pers. comm.) although a high percentage had well-defined facets, Taylor's stage 4 preservation (Parry, 1988, 56).

The inhabitants of Flag Fen and the builders of Cauldicot could have kept their axes in a better condition than those living at Oakbank. However, this seems unlikely and the differences could equally well be attributed to the conditions at the time of or after deposition. In this regard it is interesting that when Mann was examining the piles from Stoneykirk (see chapter 4) he stated that:

'the smoothness of the cut surfaces of the piles shows that the axe had a finely polished surface and a clean unbroken cutting edge' (1903, 381).

In this situation, as with Flag Fen and Cauldicot, the depositional environment was somewhat different from that found at Oakbank; the Stoneykirk piles were driven into clay. In addition the water table fluctuated over time leading to a degree of temporary drying of some of the wooden elements. This contrasts with the silty loch bed material of Loch Tay and the permanently waterlogged conditions.

An almost complete absence of tool signatures was also noted during the excavation of the Iron Age structures at the Goldcliff site, in the Severn estuary (Bunning,1991,23). The explanation Bunning gives for this is based on experimentation conducted during the Somerset Levels Project. During the Level's Project it was noted that after prolonged use of an axe: 'almost all of the minor irregularities had been cleaned away or smoothed out' (Coles and Orme,1985,30). In consequence it was proposed that signatures would be: 'more readily visible and identifiable when tools were first in use' (op. cit.). This change may be the reason for the absence of signatures on a proportion of the piles but cannot be taken as a complete explanation. Furthermore, it should be noted that the comments made by Coles and Orme referred to bronze and stone axes and not to the iron forms suggested for the constructions at Goldcliff.

Experimentation during the present study suggests that signatures can be very persistent during prolonged use of a tool. Over time there is increased likelihood of extra damage occurring; consequently damage patterns become more prevalent rather than less. This has been observed both on modern axes and on two bronze replicas made during the project. While experimental results should be used with caution (Coles,J.M.,1982,6) the archaeological material at Oakbank also confirms the persistence of signatures over relatively long periods. The material so far examined from the site has demonstrated that up to nine piles link through a single signature. The axe strikes represented by a group of this size can be well in excess of 6000 blows. Thus, the signatures of the Oakbank axes are surviving with no noticeable change over a considerable number of strikes.

Examination of the marks produced by modern and replica tools during this study has led to the conclusion that it is highly unlikely that a tool could be kept so well that it produced no signature at all. This observation is of particular relevance when considering a general purpose and well-used tool such as an axe. Consequently, a reason other than carefully kept blade edges should be sought to explain the absence of signatures on sites with otherwise well preserved wooden material. The explanation could include such factors as:

- Delay between manufacture and driving - leading to surface deterioration.
- The driving of the pile into an abrasive layer.
- The degree of movement that traffic over the structure generates on the piling.
- A fluctuation of water level.

In reality a combination of these factors will probably lead to a loss of signature detail.

Clear signatures are not found on all the piles at Oakbank Crannog. In particular, the oak timbers that have been examined from the causeway did not initially demonstrate discernible striations. This was observed during the in-situ examination of the top areas of a number of piles. To check that this was applicable to the piles as a whole, two were completely removed. Neither of the piles had definite signatures although the faceting was very clear with sharp ridges between marks (Stage 4 on Taylor's scale). Closer examination in the laboratory revealed the merest hint of striations on the facets, too faint to be of use but suggesting that damage was present on the blade at the time of manufacture (plate 7.1).

The explanation for the absence of tool signatures on oak uprights is not obvious. The generally high occurrence of signatures at Oakbank rules out factors such as the abrasive nature of the loch bed at the time of driving and other explanations have to be sought

It is possible that certain tree species record a signature better than others. A cursory look at tree anatomy will show a wide variety of structures leading to differences in wood properties (Schweingrubber, 1982). Some information is already published on this issue. Experimental work during the Somerset Levels Project has made some comment on the

working of different species with both bronze and stone blades. During this examination some reference was made to the registration of signatures on different species. For alder wood, for example, it was stated that:

'any irregularities on the axe-blade will be signalled on the alder facets and it is an easy wood to work with either bronze or stone axes' (Coles & Orme, 1985, 33).

While for hazel they made the comment that:

'The facets created by the axe are clean and sharp, and retain any axe blemish' (op. cit., 30)

Birch was also examined in this study and, although they note that the timber is rather fibrous and slightly less easy to work than alder or hazel, it is clear that signatures are well recorded (op. cit., 37, fig. 17). Willow and ash were also considered but no direct comment was made to signature registration.

Observations were also made during the current project and demonstrated that oak, ash, birch, hazel, cherry and apple wood, will all record signatures from a bronze or iron axe to an acceptable degree. Hazel, alder, birch and the wood of fruit trees record signatures to the highest quality. The fruit tree wood is particularly good presumably as a result of its tight grain. Oak and ash are not so good as the larger pores present at the beginning of each growth cycle can occasionally effect the detail of the signature record; although these species record signatures slightly less well than the other woods looked at, matches between tool marks are still very clear. Well-seasoned material will also record signatures although they are less distinct than those found on fresh wood. This would appear to ^{be} a result of the reduction in flexibility of the surface, as the moisture content of the wood is reduced.

Clearly the effect of wood anatomy cannot be the reason for the lack of signature registration on the oak timbers from the site. In the case of the timbers in the causeway the movement of the structure may be regarded as a possible cause of signature loss. The causeway is long and relatively narrow and a degree of lateral movement would certainly have

occurred. The use of the causeway, by both people and animals, would be a regular occurrence and the consequent movement might have led to subtle abrasion of the faceted end.

The above is a reasonable argument but it should be noted that an oak pile from close to the extension feature also demonstrated a lack of signatures. The position of this pile could not so easily be related to the movement of the structure and it appears likely that signature loss is a common feature of oak piling on the site whatever its position. Having said this, a young oak stake has recently been examined that does have an adequate signature. The lack of signatures may therefore only relate to mature oaks although its cause is still an enigma.

Variations in water level can influence the extent to which signatures are preserved. This is not likely to present a realistic problem on a site such as Oakbank but other crannogs, such as those found in areas of drained lochs or in intertidal zones, may suffer from this factor. It has been noted that such changes in water level can cause serious loss of information quality. This loss can be quite insidious and may lead to misinterpretation concerning the presence or absence of tool marks (French & Taylor, 1985, 151). In particular 'de-watering', even for a comparatively short time, can shift the state of the wooden material down by one or more points on the Taylor scale.

Large-scale land improvement schemes, from the beginning of the 19th century, led to the lowering of many lochs, uncovering a number of hitherto submerged sites; while providing access for many early antiquarians the wood surfaces may well have deteriorated. Thus, the lack of tool mark detail observed in the early reports may not just be the product of poor excavation or lack of observation. These comments may also be applied to the more recent excavations where fortuitously low loch levels or hydro-electric schemes have provided access to the sites (Piggott, 1952-53; Ritchie, 1942; see also Dixon, 1982b, 19).

Water level fluctuation may also explain the lack of signatures noted on the wetland sites discussed above. This might be a potential problem on intertidal crannog sites, such as those found in the Beaully Firth (Hale, 1992). However, recent examination of these sites has begun

to reveal a wealth of wooden material much of which provides evidence of excellent tool mark survival, including signatures (Hale pers. comm.).

7.1.2. Tool marks on horizontals.

Horizontal timbers at Oakbank have not, yet, yielded tool signatures although general tool shape can sometimes be seen in the form of side registrations and jams (see chapter 2).

It is important to stress that there is nothing inherent in the deposits themselves that would lead to signature destruction. Many tool signatures survive, on woodchips and other objects, within the organic matrix of the main site to the same standard as those found on piles driven into the surrounding silt. The lack of useful tool marks on elements of superstructure, such as flooring, is probably the result of abrasion during use. Signatures may survive on parts of the upper structure that are not worn through daily use or through the movement of the building, but as many of these elements are higher up in the superstructure they may not be preserved on the site.

On timber 1531, the large mortised piece described in chapter 6, no useful marks have yet been located even within the mortise holes. The removal of one of the peg pieces was conducted to establish the nature of the working and to check for possible signature survival. The peg was cut obliquely across its grain leaving neat, well-defined facets, but no useful signature could be extracted.

A lack of suitable facets on horizontal timbers is regrettable as the link between the superstructure and uprights would significantly aid the interpretation of the building as a whole. Although there is clearly less chance of finding signatures on horizontal timbers than on uprights there is still a large quantity of material to be excavated from the site. Signatures from elements of the superstructure may thus be discovered in future excavations at Oakbank.

7.1.3. Tool marks on domestic or portable artifacts

When examining the techniques of production it is unfortunate that the extensive shaping and surface dressing of a piece often obliterate crucial evidence of previous work. The same problems arise as a result of wear through use. It is thus not often possible to retrieve such specific data as blade shape and size from domestic or portable artifacts (Heal,1982,103).

Only one of the vessels found at Oakbank retains any useful facets. The butter dish found in 1988 has revealed a series of well-preserved tool marks on the base of its interior surface. These marks include not only indications of blade shape but also the minute striations of its signature (Plate 7.2 - 7.3).

All the other vessels so far found at Oakbank retain no clear marks. In most cases it is likely that wear through use would have been a major contributing factor to the loss of fine tool mark detail. This raises the question of why the marks on the butter dish should have survived so well ?. Two solutions appear probable: firstly, the dish received little use before it was broken and/or discarded or secondly, the use to which it was put did not involve heavy abrasive action and/or the facets were protected by the contents. At present the second explanation seems most plausible as traces of butter have been found in the base of this vessel. In this regard it is interesting that when Munro was describing the similar vessel from Lochlee crannog he makes much of the excellence of the tool mark survival on its base (Munro,1882,93). It may thus be argued that this artifact served a similar function to that found at Oakbank and was in some way involved in the production of butter.

While tool marks are rare on vessels from the site other smaller artifacts bear well-preserved facets. In particular a number of smaller items retain tiny and very subtle traces of working. A series of small pointed sticks found at various times during the excavation show clearly the use of a knife. The function of these items is uncertain but, whatever the reason for their production, the facets left can be excellently preserved often with a signature surviving (Plate 7.4). The small circular item that was found jointed into a stick (Plate 6.3) retains

similar minute tool marks, also with a signature, in this case underneath the point at which the carved twig joins the rest of the artifact.

It may be possible to link pieces through their knife mark signatures in the same fashion as axe marks have been used in this project. However, it is likely to be more difficult than with the marks produced by an axe. The whittling motion of a knife leads to quite distorted signatures. The narrowness of many of the pieces worked in this way also means that only a limited amount of the total blade edge is recorded. It is consequently difficult to find a sufficient width of signature to produce a convincing match.

While knife mark matches would be interesting it is important to appreciate that they are unlikely to prove as useful as axe marks. Axe marks are found on many types of material including portable artifacts, waste and most crucially in-situ material. Thus, they provide a real possibility of indicating horizontal and vertical patterning. Knife marks on the other hand are rare, less easily identified and have so far only been retrieved from small portable artifacts.

Although the use of axes is implied in the production of most of the portable artifacts clear evidence of their use is only found on one piece; the large hazel peg. This is finely faceted and signatures are apparent all over its surface.

7.1.4. Tool marks on waste.

The woodchips so far found at Oakbank Crannog all appear to be the product of axe use. Survival of tool marks on woodchips can be very good but tends to be limited in size and number. All the waste material that has been brought up from the Oakbank excavations was assessed for suitable tool marks. From this material, a sample of several hundred, 150 pieces were chosen for further examination. These pieces varied in size from 1.9 x 3.2 cm to 22 x 11.2 cm. Any woodchip that retained even the slightest trace of a signature was selected and the size distribution of the sample reflects that displayed in the excavated group as a whole. Within the sampled set some 65% were between 3 and 9 cm long. These pieces tended to have very fragmentary signatures and it was difficult to find matches between chips of this size.

Many of the Oakbank woodchips did not retain any signatures and it would seem that the production of chips is not necessarily conducive to good signature survival. During this project a series of oak stakes, 9cm in diameter, were pointed over a length of approximately 25 cm. Out of the 220 chips produced only 30 had useful signatures. Few useful marks survived on chips of 2cm or less in length; between 2 and 7 cm signatures could be found and matched together. However, if the sample was larger and mixed, finding matches between chips of this size would be difficult. Between 8cm and the maximum size in the sample (12 cm) the matches were fairly obvious but only 15 out of the 220 chips remained in this subset.

7.1.5. Tool marks on Conserved material

All categories of material discussed above have had examples conserved using a variety of techniques. As part of this project all the conserved objects from Oakbank were examined to establish the possibility of retrieving accurate information.

Oakbank material sent for conservation covers the whole range of artifacts outlined above. Three different techniques have been used, Polyethylene glycol (PEG), acetone rosin and freeze drying (see Taylor,1981,19-23).

Signature survival appears to be poor on freeze dried material. Although some pieces retained signature detail the use of casting material on these objects met with unsatisfactory results. In particular the release of the moulding material from the wood surface caused damage to the surface. In consequence the detail recorded on the cast was impaired. The pieces preserved using Acetone Rosin were slightly better but again casting could be difficult.

Signatures on PEG treated wood appear to be very well preserved although some examples have clearly lost detail. Moulding of these marks was achieved easily; release of the casting agent was straightforward and resulted in no damage. A good example of the survival of signatures on conserved material was seen during this project when a waterlogged pile cast underwater in 1992 was found to match a pile conserved in 1982 (see Group S, chapter 10).

It is clear, however, that survival of tool marks on conserved material is not guaranteed. A number of objects can be shown to have lost much of their original tool mark information. Reference to comments made by Dr. Dixon at the time of excavation demonstrate this. It was said of the 'canoe paddle', for example, that: 'toolmarks are clearly visible on the blade' (Dixon,1984b,228). No toolmarks of any description now survive. Similarly, pieces photographed at the time of discovery demonstrate well-preserved signatures. Examination of these pieces now shows them to be damaged or completely eradicated. Such findings confirm the need to do all detailed recording before conservation.

A number of objects have been stored in the dark, in water, since their discovery. Some of these date back to the beginnings of excavations at Oakbank and have been stored for over 12 years. The signatures on a number of these pieces are excellent and appear to have suffered no significant deterioration. Indeed the signature group (Group S) that contained the in-situ and the conserved pile also matched with a timber that had been in long-term wet storage.

7.2. The woodworking tool kit of the Oakbank dwellers

Crannog sites have so far given very little evidence as to the actual tools used in their construction and during the inhabitants' everyday life. In a survey of the archaeological literature on crannogs Oakley tables only 17 tool finds made during archaeological excavations of Scottish crannogs (1973,Table III). Thus, the examination of the tool marks gives a vital insight into an otherwise rarely glimpsed aspect of the occupants' lives.

The reconstruction of the Oakbank tool kit is presented, at this stage, in purely functional rather than typological terms. The extent to which typology may be assessed from tool marks will be considered more fully in chapter 15.

The tool marks at Oakbank have so far suggested that the woodworking tool kit of the inhabitants included axes, knives, gouges, chisels, awls and hole boring equipment.

7.2.1. Axes

The axes used on the site are the main type of tool mark examined during this thesis and will only be briefly discussed here. All the axes so far reconstructed are quite small. The largest has a complete blade width of 7.9 cm while the smallest is only 4.5 cm in diameter. All the blades have gently curving edges (see chapter 11).

7.2.2. Knives

A number of small wooden points clearly demonstrate the use of a knife (Plate 7.4). Many of these points have signature fragments that clearly reflect the whittling motion of the tool.

Knives are well attested to from the earliest tool kits and are well known from Late Bronze and Iron Age contexts. During both periods they are found in tanged and socketed forms (e.g. Pearce,1983,44;Manning,1985,108-123). Both forms would be capable of producing the marks observed. A tanged bronze knife is known from the Late Bronze Age hoard at Killin, at the southern end of Loch Tay (Schmidt & Burgess,1981,plate 141,B4). However, it is not considered possible to distinguish between marks left by bronze knives and those made in iron. Such a distinction is made all the more problematical as the motion of the tool and the lack of edge registration make any absolute definition of blade shape and size difficult.

While it is difficult to distinguish between the marks produced by a bronze knife and those produced by an iron knife it is interesting that an iron find made close to the Oakbank site in 1992 may be the remains of such a tool (fig.7.1). The piece was found lying on the silt close to area A2. The object was out of context when discovered but it is likely that it had fallen from the organic deposits at the edge of A2. It is very similar to objects that have been described as knives (Manning,1985,108-123). The current form of the piece does not immediately suggest a knife but as Manning argues many such objects: 'have been repeatedly whetted until the blade has become a travesty of its original shape' (op. cit., 108). An iron find from the site of Hod Hill closely resembles that found at Oakbank and is categorised by

Manning as the remains of a type 15 knife, the most common form of Iron Age knife (op. cit., plate 55, Q54). In this form both the back of the knife and its blade are off-set from the line of the tang.

If the iron find from Oakbank is the knife that produced the wooden points that have been found it would be difficult to prove. The details of the blade edge have clearly been destroyed by corrosion and it is no longer possible to reconstruct the tool's signature.

The large hazel peg found in 1981, was referred to by Dixon as having been manufactured with: 'the use of a sharp knife, about the size of a modern pen knife' (Dixon,1984b, 227). However, careful examination of the facets and orientation of the signatures on this object clearly suggest that it was produced by gentle axing. Indeed the production of such an item can be produced far more rapidly with an axe than it can be by whittling with a knife. It is important to realise that smaller objects can be made using subtle axemanship as it is the axe signatures that are by far the most useful of all classes. If it can be shown that an axe has been used to work a particular small find this may well link the fashioning of an object to a particular phase of building. Furthermore, in the same way as wood chips can associate stratigraphical layers to verticals so too may other artifacts.

7.2.3. Gouges / Chisels

The base of the butter dish, like the vessel found at Lochlee crannog (Munro,1882,93) clearly shows the use of a gouge. These marks represent a tool with a blade that was curved in cross section probably slightly more than 23 mm in diameter (plate 7.2 - 7.3). Such gouges are highly useful tools for hollowing out small vessels.

Small gouges are relatively common within a Late Bronze Age technological context and are found in a number of hoards, including the one at Monmore, Killin, at the southern end of Loch Tay. This blade edge of this find is about 17 mm wide (Schmidt & Burgess,1981,plate 141B). Socketed gouges of a similar size are also found during the Iron Age (Manning,1985,24-25). Experimental use of these forms of tool is required to establish

whether there is any major functional difference between them. Unfortunately it was not feasible to make replicas of these tool forms during the current study and consequently it has not been possible to suggest which type was responsible for the marks on the interior of the butter dish.

A large, deep, oval dish, found in 1990, would also have been manufactured with the use of some form of gouge although possibly, in the case of a vessel of this size, a small adze or gouge adze would have been more effective. The gouge adze is hafted as an adze but the blade has the cross sectional curvature of the gouge. A similar tool is possibly represented by a member of the Adabrock hoard (a socketed implement with no loop and a dished blade) (Schmidt & Burgess, 1981, Plate 144, A11).

Alternatively this dish may have been produced using a curved socketed knife which first appears in the Late Bronze Age (e.g. Schmidt & Burgess, 1981, plate 143, B2). It is possible that an axe, gouge-adze and curved knife were all used in the production of this bowl with the curved knife used for final finishing. The use of these three tools has been used for spoon production until quite recently in West Wales (Edlin, 1949, 78, Plates 79-81). Unfortunately, no marks survive on this piece but an axe and a gouge would have been essential. A circular plate from Oakbank may also have been originally worked with a gouge although the woodworking traces no longer survive.

7.2.4. Hole boring tools

Some evidence for hole boring tools came from what may be regarded as the waste product of hole production. A few small circular plugs of wood have been found amongst the layers on the site. One piece in particular demonstrates this feature (Artifact No. 5166). It has a central hole and a series of grooves spiralling around its edge (Plate 7.5 - 7.6). The piece tapers slightly from one side to the other. The exact form of the bit used to produce this piece remains enigmatic.

By the closing centuries of the first millennium BC an auger shaped like a spoon was certainly playing a significant part in the lives of the communities of southern Britain at least. Indeed it has been suggested that the auger is one of the pieces of technology that the Romans gained when they came into contact with the peoples of Gaul and Southern Britain (Weeks, 1982, 55-56). Its role in the production of chariot wheels was crucial. No evidence for the use of this type of auger has been found on the Oakbank material. Indeed, the only holes found within the artifacts and timbers from the site appear to have been chiselled or gouged out rather than bored.

The base of the butter dish contains two complete holes and the remnant of a third. The breakage or erosion of this piece has conveniently exposed the working on the interior of this hole. The exposed surface clearly shows a small tool mark on the side of the hole, its size and shape are reminiscent of that used to produce the 'butter' dish interior. The twelve holes found along the mortised timber (fig. 6.3) appear to have been chiselled out. For the most part they are square in plan and are clearly not worked by a drilling motion.

7.2.5. Awls

One of the smaller wooden objects found at Oakbank appears to show the use of an awl in its production. The piece is a smoothed round object, 14.2 cm long and 1.45 cm in diameter, and burnt at one end. It seems probable that it was a handle to an implement the functional end of which burnt away. Set into the upper part of this handle is a perforation possibly allowing it to be hung up. Within this hole two semicircular shapes are apparent. This suggests the use of a small pointed tool hammered twice through the piece to create a perforation of the desired width. Similar marks appear through the carved woodchip displayed in plate 6.3. Awls are known from both Bronze and Iron Age contexts and it would be difficult to distinguish between the marks left by tools from different periods.

7.3. Tool classes not represented by the Oakbank material.

7.3.1. Saws.

Despite the description of layers containing: 'what appeared to be deposits of coarse sawdust' (Dixon,1984b,206) there is a complete absence of saw marks on timber directly related to the occupation of Oakbank Crannog.

The positive identification of substantial saw marks at Oakbank would suggest the everyday use of iron tools. The technical problem of producing large, tough and flexible metal saws with fine edges does not appear to have been solved by bronze using peoples (Arnold,1982,115). Although bronze saws are found in the British Isles they are both rare and very small (e.g. Pearce,1983,Plate 11,artifact 94a), and would only seem capable of very limited work.

It is only with the introduction of iron that saws become a practical addition to the woodworking tool kit (Manning,1985,19-21), although the earliest date at which they came into common usage within Britain is uncertain (see chapter 15 for discussion on the problems of identifying early iron work). It may only be through the observation of such marks on wooden material from well-dated sites that this technological question can be resolved.

Other crannog sites in Loch Tay have given tantalising glimpses of such technology at work but it is too soon to say exactly how the pieces observed relate to the rest of the site. A site off the end of Craggan pier, on the southern shore of Loch Tay (Dixon,1982b,33; fig.3.1 site 12), has, for example, a number of timbers projecting from it the largest of which: 'shows evidence of having been cut by a saw in two places' (Dixon,1984b,plate 13).

7.3.2. Adzes

Adze marks are not specifically found on any of the timbers looked at so far. Such marks can be difficult to identify, they are often produced during a finishing process in which the

intention is to leave the surface as smooth as possible. In circumstances where they are positively identified it tends to be the situation in which they are found that suggest their use. For instance, the location of tool marks in the restricted environment of a hollowed out boat can only really be considered as the product of an adze (e.g. Goodburn,1989,99).

Clear examples of the use of adzes are, however, sometimes identified. At the Iron Age trackway site of Corlea 1, Co. Longford, Ireland, for example, the surface of a large mortised plank has been dressed using such a tool (O'Sullivan,1991,vol.ii,72,fig.64). At Oakbank Crannog it is probable that adzes were used but as planking or well-preserved worked horizontal material has not yet been found marks have not been positively identified. The production of the large oval bowl certainly implies the use of an adze for hollowing but no actual marks survive.

During the Bronze Age in Britain it may be argued that the concept of the adze had not been fully developed. No blades are found within Bronze Age contexts of the British Isles that have been shaped or sharpened like an adze. Clearly tools were being used hafted in the same manner as an adze from the numerous finds of dugout boats. For the most part these appear to be axes re-hafted, with the width of the blade at right angles to the haft. There are a few cases where the form of the tool suggests hafting as an adze but these are rare (e.g. Grinsell,1953). Furthermore, even in these cases the edge of the tool is sharpened in the same manner as an axe. During the current study a socketed bronze axe was hafted as an adze and was found to be relatively effective for hollowing out; it was, however, difficult to produce a very fine finish.

True iron adzes will produce a much finer surface than could be produced by either socketed bronze axes or early iron age material. True iron adzes are clearly represented in later iron working hoards such as Blackburn Mill, Berwickshire and Carlingwark Loch, Kircudbrightshire dating toward the end of the first century AD (Manning,1972,232-233;see also Manning,1985,16-18). They are also present on earlier sites in southern England such as Meare Village East, mound 22, dating to around the first or second centuries BC

(Coles,J.M.,1987,fig.3.52,no.157) or Danebury Hillfort, Hampshire (Cunliffe,1991,fig.14:4 no.6). However, the date at which they first come into general use remains uncertain.

7.3.3. Heavy duty axes.

No axe mark over eight centimetres has yet been found on the site and clearly even the main constructional work was being conducted by fairly small axes. This aspect of the Oakbank material is discussed more fully in chapter 15.

CHAPTER 8

Previous tool mark examination at Oakbank Crannog

The present examination of the toolmarks at Oakbank Crannog owes much to the work conducted by the author as part of an undergraduate dissertation at the Institute of Archaeology, London (Sands,1989). The following short chapter reviews that work as a background to the next chapter, which covers the methods and materials used during the current examination.

8.1. The data set.

Six closely associated piles were chosen for closer examination during the undergraduate study. The piles were removed from the south side of the extension feature, for examination in the laboratory. At this stage work was based in London so long distance transportation was necessary. Transportation and storage were easily achieved for six piles but it was obvious that for any broader study a different approach had to be sought. Work would need to be conducted much closer to the site and a system had to be found whereby the facet details could be accurately recorded in-situ (see chapter 9).

All six of the piles had more than 60 facets and in one case more than 120 were clearly resolvable. The examination of these facets demonstrated the high quality of the preservation at Oakbank. All the timbers had facets upon which signatures were clearly visible. It was immediately obvious that the tool marks being looked at were produced by a metal blade. The neatness and length of the facets were unlike anything that had been observed on timbers known have been manufactured using a stone axes. Marks left by stone tools are usually shorter and the facets appear less distinct, being slightly more ragged than their metal counterparts. These observations reflect those made by Coles although he also notes that the relationship between tool and facet is a complex interaction:

'Facets produced by stone axes tend also to be shorter than those from a bronze axe, but this too reflects not only wood species but also angle of cut, stone axe users knew what their tool would and would not do, and rarely attempted a shallow angle or slash cut, whereas metal-axe users often overestimated their ability to successfully cut through a stem in one shallow angled chop.' (Coles and Orme, 1985, 27)

While the use of metal tools was obvious both from the facet form and the date of the site it was not felt to be possible to clearly suggest whether the axes used were of bronze or of iron. It was clear that the marks produced on the timbers were not those normally associated with an iron shaft-hole axe. The Oakbank tool marks were mostly slightly dished. The facets produced by shaft-hole axes, by contrast, tend to be flat rather than concave in profile. This question is considered in more depth in the current project (see chapter 15).

8.2. Methods of recording.

During the undergraduate study the recording of signatures was mostly conducted using scaled photographs and drawings. In particular a form of bar code was developed by overlaying photographs with clear plastic and tracing features off as a series of linear bars. This appeared fairly effective but it is now felt that this approach could lead to errors particularly when complex marks are being examined. Indeed careful examination of the match made between piles 1049 and 1050 during the first project now appears unlikely. The superficial similarity between the marks was extenuated by the simplified bar code approach and when these two were cast, during the present study, the match was not obvious. Indeed consideration of the tool shape and width has confirmed that the two axes were different.

It was only at the very end of the undergraduate work that the most efficient method of signature comparison, the use of moulding material, was established. Moulding the facet surface could be easily conducted using any one of a number of materials. Once moulded any two facets could be compared side by side without the problems associated with dealing with large pieces of wet wood.

During the undergraduate project it was suggested that it would be advantageous to find a material that may be easily used underwater allowing for the recording of in-situ timbers. Dental moulding material appeared to be the best candidate for this job. It was not possible, during the initial project, to experiment with this assertion on in-situ material, although some experimentation showed good results in test tanks. The full application of moulding techniques, particularly on submerged material, has been one of the primary advances during the current assessment (see chapter 9).

8.3. Quantification.

The undergraduate study also examined some methods by which accurate measurement of tool signature features could be achieved. In doing this a number of techniques were considered and a machine called the 'Reflex Microscope' chosen for use. This microscope allowed for non-contact measurement in three dimensions.

The machine was easy to operate. It consisted of a specially adapted binocular microscope that could move in all three planes using x, y and z controls. On looking through the eye piece a light spot was visible in the centre of the field of vision. The light spot appeared to move across or in and out of the surface being viewed as the x, y and z controls were turned (Scott,1981). A push of a switch recorded the position of each of the controls. By keeping either of the horizontal axes constant a profile across a signature could be built up. During the original study the measurements were made across the wood surface but they could more conveniently have been done on moulded copies of facets. The results from this process were good and the close accurate examination of the signatures provoked a number of ideas not least of which was the significance of inter-ridge distance variability (see chapter 2).

When the Reflex Microscope was borrowed from the photogrammetry department of University College London it was hoped that it might provide a basis for an automated matching process. However, to produce a single profile across one facet required well in

excess of 100 readings, which took time even for an experienced operator. As signatures are variable in form along their long axis, as a result of erosion or slight shifts in the direction of force of a cut, a number of profiles were required to produce a complete picture of a mark. It was felt, because of the recording time required, that this, and similar techniques, were not rapid enough for the purposes of signature matching. Certainly, this method did not appear to provide a significant advantage over manual visual comparison. The use of this machine has thus not been pursued further in this thesis. The primary form of signature matching remains a basic, but effective, visual comparison using, in the current study, moulded copies of the facet surface. If automated matching is to be considered, digital image processing is now considered to be the best approach (see chapter 17)

8.4. The results of the undergraduate study.

The pilot study demonstrated that given careful observation links between worked wooden objects on the site could be established by comparing their signatures. Of the six pieces it was argued that three were fashioned with one axe, two with a second and the final piece was cut by another axe.

While the second group is now no longer considered to be correct, there was no doubt after the pilot study was completed that further work at Oakbank would prove fruitful. The reasons for the initial mistakes were methodological, resulting from the use of a matching process that was based on a simplified representation of the signature rather than the original detail.

The undergraduate work focused only on signatures and no attempt was made to reconstruct blade shape and width. Consequently, full blade definition was lacking. The current study has examined full blade definition in far more detail. The quality of match has also been more carefully considered in the current examination. The core signature groups represented in this thesis include only those where matches are the same in almost all particulars. Possible matches are discussed only once clearly associated groups have been

established. During the pilot study the limited number of piles examined did not provide the opportunity to observe the clear quality of matches that have now been found. In addition without the use of casts the clarity of certain matches was difficult to fully appreciate.

CHAPTER 9

Methodology

Moulding materials were of special importance to the success of this project. In particular the discovery of a technique that could be used underwater has proved invaluable. The following chapter examines the use of these materials; establishing the case for in-situ casting and assessing the effectiveness of the products chosen. This chapter also briefly covers other recording methods used and describes the way in which the groups described in chapter 10 were established.

9.1. Moulding

Replicas have been used in scientific examination for well over a hundred years (Claugher,1988,14). Use of moulding materials has a number of advantages not least of which is that it allows for the : 'extensive technological examination of an artefact ... quite removed from the artefact itself' (Goodburn-Brown,1988,55). Furthermore, as a consequence, it: 'encourages exchange between researchers, allowing a greater circulation of information with minimum movement of originals' (d'Errico,1988,163).

The advantage of moulding was realised during early investigations of tool marks on wood found in Scotland. John Grigor's account of crannogs located in the Loch of Clans, Nairnshire, illustrates an early attempt to preserve the surface detail of worked wood:

'I had one of the oak piles drawn up it measured 13 feet in length ... Whether the pile had been pointed by a stone hatchet I cannot say. When raised from the water the cutting seemed to me to be of that character. When wood dries, however, the peculiar markings very much alter, and Mr. Forel did wisely in taking his plaster casts from the pile ends when freshly drawn and saturated with water.'
(Grigor,1864,335)

Mann's study of marks left on timbers in Wigtownshire also involved the casting of ten pile ends in plaster (1903, 382-383, fig.5).

More recently silicone rubber has been used to good effect in the examination of tool marks on timber. Goodburn's study of the working traces left on a Late Saxon logboat from Clapton is a good example. By taking casts he was able to examine details under ideal lighting conditions. Removing the problems of dark wood surfaces and difficulties of access allowed for detailed measurements of tool mark features and attempts at reconstructions of the tools used (Goodburn, 1989, 99).

Moulding materials also provide the perfect solution to the rapid recording and archiving of small areas of fine detail that might otherwise be lost. This is a point clearly made in the English Heritage wood recording guidelines:

'it is unlikely that conditions will permit every piece of structural wood not only to be recorded but retained for future study and analysis'
(Coles, J.M., 1990, 12, Guideline 9.6).

The use of these materials during the current study has allowed for the beginnings of a tool mark archive for the Oakbank site. This archive does not require the same storage space or maintenance as that of the timber itself. Furthermore, its stability allows for re-analysis or further analysis to take place without additional handling the original material.

The advantages of using moulding techniques are clear. However, it was felt that it would also be advantageous to be able to employ such material underwater on in-situ material. The reasons for doing this and the techniques employed are outlined in the following sections.

9.1.1. The case for in-situ recording.

The development of an in-situ moulding procedure was vital to the success of this project. It allowed facet details to be recorded before it was physically possible to remove the timber. This was particularly important on the main mound where facet surfaces were uncovered on piles that were driven deep into the organic material. It was not possible to remove these timbers before excavation of the surrounding material without compromising the stratigraphy.

If timbers are left in place until they can be lifted erosion of exposed surfaces occurs. This is a point made during Taylor's examination of the tool marks of the Iron Age Farmstead settlement in the Assendelver Polders, when she comments that:

'The importance of rapid examination of timbers of this sort cannot be over stressed: as timber deteriorates (as it must do once it is disturbed), the quality of tool-marks will also deteriorate.'(Therkorn et. al.,1984,366)

The erosion of the timber surface can be quite insidious and, although faceted surfaces can look quite well preserved, signature detail may be completely lost.

Even if timbers can be removed it may not be practical to raise all the pieces that require observation. Storage and conservation facilities, as well as time constraints, may limit the quantity of timbers that can be lifted within a single season. In-situ casting allows for blanket coverage of a broad range of timbers. The results of these casts may then be used to select certain timbers for lifting or further in-situ examination.

9.1.2. Underwater moulding - the choice of materials

Some underwater moulding of archaeological timber features has already been conducted. In 1981, for example, L.D. Murdock and T. Daley wished to record: 'ship's structural features in-situ' (Murdock & Daley,1981,337). They were particularly interested in tool marks and other small scale features on the timbers of the Basque whaling ship the San Juan. During this project they used polysulfide mould compounds and dental plaster to record the fine detail of the wood surfaces before the material was raised.

Murdock and Daley achieved good results but after careful consideration it was decided that their system was not a practical option for the Oakbank material. Not only did the materials they used have to be carefully mixed before diving but the moulding compounds required more than 24 hours to cure. The low viscosity of the uncured material and the long setting time would be problematical when casting against a vertical surface. A well-sealed

method of containing the material would have to be designed to cast the surfaces of upright piles.

For in-situ recording to be a practical option at Oakbank the material chosen had to conform to a number of criteria:

- Safe to use.
- Easy to mix.
- Easy to apply.
- Possible for it to cure underwater.
- Rapid curing time.
- Only incurs, at most, minimal damage to the archaeological material.
- Replicates the features with sufficient accuracy.
- Easy to make multiple copies of the original cast.
- Lengthy shelf life.

Above all it was hoped that a system could be found which could be used at any stage during excavation, without the need for too much preparation.

A number of moulding materials will work on waterlogged timber. During the original undergraduate assessment of the material (see chapter 8) two forms were assessed:

- Dow Corning's 9161 silicone rubber.
- Express 3M's Hydrophilic addition cured vinyl-polysiloxane.

Both of these products were found to work well when casting tool marks in the laboratory. The second of these met most of the criteria suggested above and was, therefore, chosen for further field trials. This material is a product regularly used by dentists to produce accurate moulds of patients' palettes. It is self contained, easy to apply, and safe to use.

The material used during this study was not that produced by the 3M company. Brands were instead chosen because of their use in Edinburgh University's Conservative Dentistry Department and the consequent technical assistance that could be provided. The process involves the use of three main products:

- '*Optosil*' - backing material consisting of a putty base and a paste activator produced by Bayer Dental.
- '*Reposil*' - Hydrophilic Addition Cured Vinyl Polysiloxane - which consists of two parts mixed in equal proportions of base paste and catalyst. This is essentially the same material as the "Express 3M" material used in the original undergraduate study.
- '*Kafir 'D'*' - Dental Stone - fine grade plaster for positive moulding of the casts back in the laboratory.

These materials were originally assessed submerged in a small tank of water. These tests demonstrated that the material would indeed cure in an entirely submerged situation.

9.1.3. Underwater moulding in practice at Oakbank Crannog.

The dental moulding technique is a straightforward one involving two steps. The first is the use of a heavy putty backing, the Optosil material, to provide the rigidity for the cast, and the second uses a finer wash, the Reposil material, to provide precision; this is referred to as the 'Reline Technique' (Phillips,1982,151). Initial field trials of these materials were conducted in 1991 and it proved to be an easy system to use.

The first stages involves exposing the faceted surface of the pile by excavating around its circumference. A facet can then be selected and silt removed from the surface by gentle brushing (plate 9.1.i). The diver then mixes the putty with the paste catalyst. Both these materials are viscous and easily handled without mess. The putty and catalyst are kneaded until thoroughly mixed. Once mixed the material is shaped to the rough dimensions of the facet to be cast. While the putty is still soft, a rubber stamp is used to impress the timber number and facet code into the back of the cast. The backing is then pushed against the chosen facet (Plate 9.1.ii). In the waters of Loch Tay the backing material takes approximately 10-15 minutes to fully cure. The curing time is temperature dependant and the colder the water the slower the setting time. Once cured, the backing is removed from the facet and a light covering (approximately 2-3 mm) of the fine material is added (Plate 9.1.iii). The cast is then reapplied to the wood surface (Plate 9.1.iv). The finer wash material, like the putty backing, takes longer to cure when the water is cold but in general all the casts were

ready for removal in approximately 20-25 minutes. This setting time is considerably faster than the 24 hours quoted by Murdock and Daley for the polysulphide rubber.

The application of the fine material is easily conducted. The development of this material for dentistry has led to a very convenient system. A gun shaped applicator receives a double barrelled container in one barrel of which there is the base material in the other the catalyst, a plunger attached to a trigger allows material from both barrels to be extruded in unison. Each cartridge (70 ml) is enough for approximately 8-10 casts. Attached to this container is an applicator nozzle. The plastic screw inside the nozzle mixes the two materials as they are squeezed out of the container by the trigger of the gun mechanism. Thus, all the mixing is done automatically and delivered directly to the desired place.

The Murdock and Daley article (1981), suggested that there could be a problem in retaining moulding material against a vertical surface. However, the slightly more viscous quality and the rapid curing time of the material used in this project meant that only the most basic retention was necessary. It was found sufficient to excavate down the side of the pile to a position just below the facet to be cast, where a smooth horizontal stone or piece of lead sheet was placed to stop the cast sliding downwards. Against the back of the cast was placed another piece of lead sheet, this provided sufficient pressure to prevent the cast falling away from the wood surface.

The long term stability of the materials chosen for use in this project is considered to be excellent as long as they are handled with due care. Some small dimensional change of the material will occur in the material with time (Phillips,1983,146). However, it is also true to say that, because the silicones being used are addition cured, there is a lack of byproduct in the curing process that leads to far less initial shrinkage than that produced by condensation cured materials (op.cit.,147,fig.10.3). As soon as a cast has been taken a positive copy can be easily produced. The fine grain plaster, Kafir "D", also used in dentistry, was found to produce excellent results. The dental stone copies of the original silicone moulds are dimensionally stable although more prone to physical damage.

The use of the moulding materials in dentistry ensures that they have been rigorously tested for safety. As they are intended to be used in the mouth they are probably the safest that could be used. By contrast, materials such as Dow Corning 9161, or more precisely its catalyst (9162), have very strict health precautions attached to their use. Thus, while on financial grounds their use is recommended for recording in the laboratory the necessary health precautions have to be taken into consideration.

9.1.4. Difficulties with the moulding system.

The moulding system chosen for use at Oakbank has worked extremely well. However, there were some initial problems. Of most importance was the effect that submergence appeared to have on the catalyst of the Optosil putty backing material. It was found that after approximately 1 - 2 hours underwater the paste started to harden. At the start of the excavation season the tube of paste was being taken down and simply squeezed on to the putty. The hardening effect was restricted to the nozzle of the tube and consequently blocked the flow. This could be alleviated for a while with the use of a pin but this seemed an unsatisfactory answer.

As a temporary solution to the problem small sealable tubs were filled with the material. This did not stop the hardening but the material could at least be accessed easily and used before hardening had fully occurred. This problem introduced the inconvenience of having to return to shore at regular intervals to pick up more material. Small syringes were also tried but proved impractical and easily lost, and were quickly abandoned. Consultation with the manufacturers did not provide an explanation for this problem.

Fortunately, an alternative backing material existed that consisted of a two part putty. In this case the catalyst was incorporated with a filler material and the mix of catalyst to paste is 50/50. Both parts can be stored in small finds bags, they do not float and they are both more stable in a wet environment. Their use during subsequent field seasons alleviated much of the frustration and waste encountered during the summer of 1991. Eventually the putty catalyst

will also harden on its own but this happens in a matter of days rather than minutes. It is still, however, a wise precaution to take down only as much material as the diver is likely to use in a single session to avoid contamination of unused stock.

It is worth pointing out that a number of the dental moulding materials use the same catalyst as that used with Optosil; 'Xantopren Plus' and 'Provil L' (produced by Bayer Dental) have both been used with acceptable results on Oakbank material. These were both considered to have an acceptable level of accuracy in d'Errico's study of various products available to archaeologists (1988,157). However, clearly the manual mixing system and the catalyst problem make both of these products an unwise choice for on site work.

One additional problem was encountered when using this system. The outlet holes from the two barrels of the cartridge sometimes proved problematical once underwater. They can become blocked by small plugs of cured material. It was therefore found useful to carry a small pointed object to clear any blockage. A jeweller's screw driver was found to be most convenient.

9.1.5. Observation and recording: a choice of scale.

The scale at which tool mark signatures should be observed is an issue that merits some consideration. A number of tool mark studies have employed detailed Scanning Electron Microscope (SEM) examination in combination with casts. The use of the SEM in identifying the use of individual tools used during metalworking is considered to be of great value (Goodburn-Brown,1988,56) and was also put to good use in the examination of the tool types used on bone material (Olsen,1988c,341). In some cases the examination of the manner of tool use can also benefit from the high magnification and great depth of field provided by the SEM, Gwinnett's study of ancient lapidary techniques used on a Cycladic Statuette is a case in point (Gwinnett,1983).

When Benner Larsen examined the metal plates of the Gundestrup Cauldron he chose to study his casts of the tool marked surfaces under the SEM to levels of x450 or more (Larsen,

1987, 400). It is questionable whether tool marks on timber require such close up investigation. Many of the most important elements of the mark would seem immediately obvious to the naked eye. The practical use of taking examination beyond this or minimal magnification would appear doubtful. However, an examination was conducted on the Oakbank casts to see if there were any details in the tool mark that had hitherto been unobserved and which might prove useful in the interpretation and comparison of the signature.

There was an additional reason for this close up examination. It was suspected that microscopic detail recorded by the moulding material was limited by its use in a wet environment. The resolution of Reprosil at high magnifications has also been called into question by researchers as had other dental materials (Claugher, 1988, 15). However, these doubts were raised in the context of high magnification SEM examination (op. cit., figs. 9 & 10) and it was uncertain whether such high magnifications would add anything to the current project. The material suggested as the best by Claugher was that tested during the original undergraduate project of the Oakbank material, Dow Corning's 9161. However, the use of Dow Corning material was impractical in a submerged situation for the reasons laid out in the assessment of the Murdock and Daley approach.

To look at these issues a cast was taken to the SEM laboratory at King's buildings, University of Edinburgh. It was decided that a series of photographs should be taken of regions showing the most detail at increasing levels of magnification until detail became unclear. The photographs were taken on Kodak Timax 6052 film and three characteristic shots are shown on plate 9.2. It can be seen that, at low magnifications, signature striations are clear and wood features, such as growth rings, are visible. At x150 striations are still just visible but no extra useful detail is apparent. At a magnification of x300 features are no longer clear and interpretation would be extremely difficult without reference to the other pictures.

The lack of resolution at x300 indicates blurring due to the thin water layer on the wood surface. This cast was taken on a wood chip with as much surface water as possible removed. It thus represented an ideal cast and moulds taken underwater can be considered as more susceptible to this problem. Although this is the case lower magnifications indicate that even if the moulding was more accurate additional signature information may not be resolved. The fibrous nature of the wood places a limit on the absolute resolution of tool edge damage on the wood surface.

SEM examination of tool marks directly from the wood surface to assess the specific difference between the cast and the original would be interesting. However, most of the timbers bearing such information are too large to be looked at with the SEM. Removing a small section might be an option but wet objects cannot be examined as: 'the microscope will not be able to achieve operating pressure if there is vapour being given off by the specimen' (Claugher,1988,9). The solution to this would be freeze drying but notwithstanding the extra time and money that this would add it is uncertain how well the surface detail would survive. Considering Oakbank material already conserved with this method it would seem inappropriate (see section 7.1.5).

The low magnification SEM photographs of the casts are of a very good quality. SEM photographs in contrast to ordinary microphotographs allow for a greater depth of field allowing all parts of a curved surface to be in focus simultaneously (Olsen,1988c,341). However, given the added cost involved in producing these, particularly when considering bulk samples (Olsen,1988b,3), it is not a path that is worth considering unless all other methods prove inadequate. Furthermore, as the assessment of facets and the combination of signatures are eventually thought to have a partial role as an on site process the use of such equipment is impractical.

Standard microscopic examination directly from the wood surface has already been considered and found to be impractical for the majority of the data set under examination (see

chapter 8). However, it has been found useful to examine casts under a microscope at low magnifications when detailed measurements are required for such tasks as blade width determinations. Equipment normally used in the production of tree ring measurements has been found to be useful in this regard.

9.2. Additional recording

The moulding process described above represented the principal recording method for this project. However, other features have to be recorded to put the casts in context. The following sections give a brief commentary on the methods used.

9.2.1. Drawing.

Drawing has been conducted largely at 1:1 especially in the case of feature details (see Coles, J.M., 1990, 10). In the case of the raised uprights a selection has been carefully drawn to include all facets, indicating strike direction and orientation. A transparent table with adjustable legs was constructed which enabled the object to be traced without contact. This has proved to be a relatively efficient way of quickly producing detailed drawings. Small objects such as wood chips or artifacts can be quickly recorded using a smaller version of this table.

9.2.2. Photography.

Taking photographs of signatures directly from the wood surface is often problematical. Wooden material can be dark, light absorbing surface, and the finer details are difficult to highlight. In addition, the wetness of its surface can cause unwanted glare in the photograph. Most photographs taken during this project have been conducted using a Pentax 35mm camera and Illford Delta film (400 ASA) with strong side lighting to enhance the ridges of the signature.

It has been found useful to allow the surface to dry a little before a photograph is taken. The area to be photographed can be dried in relative isolation using an absorbent cloth. No harm is done to the timber provided it is not left to dry for too long and the resultant photograph picks up far more of the detail. Strong lighting should be used sparingly when dealing with wet wood as it can cause rapid drying.

9.2.3. Data storage.

Borland's Paradox 3.5 database program has been used to store information about the timbers examined. The database was used to store descriptions and dimensions of particular timbers. Of particular importance to the present study was the fact the database allowed for a relational design. A single record in a central table could relate to many records in an associated detail table. Each timber could thus be associated with a series of records that detailed each facet cast. This also allowed for the possibility that a single timber might have been worked by more than one tool. The identified tool could be associated with specific facets and casts rather than generally to a complete timber.

The facet detail table included information on whether the facet had signatures, side 1, side 2 or jam features. In addition a field was included which recorded the tool group to which the facet might belong. It also included information on tool mark width and length. Thus, cast facets fitting particular criteria could be easily retrieved.

An additional table stored the position of the timber. This has been designed so that its output can be used directly by a plotting program (AutoSketch for Windows). Consequently, timbers can be selected that fit certain criteria, such as belonging to a particular signature group, and then plotted to examine distributions. The plans shown in chapter 10 have been produced using this technique.

9.3. Forming groups

Basic data examination has been done largely manually. Once casts were taken their facet dimensions were entered into the database already mentioned after which each cast had two positive plaster copies made. This allowed for the originals to be stored away and not handled unless further copies were required. When the plaster copies had become solid they could be carved down to bisect the signature at right angles. Casts could then be slid past each other to determine whether any fit was possible between them. Strong side lighting highlighted signature details and considerably aided comparison. This was found to be an efficient method of amassing the major connections within the data set. The groups of casts bearing the same signatures are presented in chapter 10.

To make sure that any given pair of casts were only examined once a large matrix was drawn up that was stored as a series of spreadsheet files. This displayed the number of each cast on both axes. The points of intersection held a value indicating whether a match was considered possible. The value was taken from a sliding scale that consisted of a number from 0 through to 5. The scale was as follows:

- ① Absolutely no discernible match can be found.
- ② Two or three ridges coincide on one cast with two or more on another at one position but other ridges on the piece do not appear to match.
- ③ Three or more ridges coincide but the rest do not.
- ④ A number of the ridges on the pieces appear to coincide but there are still anomalies.
- ⑤ Most features on the facets associate but the match is not 100% perfect, possibly some of the finer details are missing on one of the casts. In this case the features on individual ridges also correlate between two casts.
- ⑥ A complete match - all the main ridges on the pieces match and most of the finer details clearly also do.

At first sight this may appear to be a rather subjective scale. However, there are some crucial points to make. Firstly it was abundantly clear when there was no similarity between casts whatsoever. Secondly when two casts fitted well the extent of the fit was so clear that there was no doubt as to its veracity. Thus, levels 0,4 and 5 could be relied upon as an objective

assessment of the matches or lack of matches present. Levels 1,2 and 3 were, admittedly, far more subjective but their role was to flag certain possibilities in the hope that more conclusive proof could be found, such as blade shape similarities. No connection at the 1,2 or 3 level was used to form the core group relationships that are discussed in chapter 10. Thus, all core groups were built on the firmest evidence possible.

All the groups presented in this thesis have been produced using visual matching only. However, chapter 17 introduces a technique that might in the future be used to automatically sort through images of casts for matches. Although this method is only at an experimental stage it does suggest a way in which tool signatures could be quantified and statistical analysis applied to the matching process.

9.3.1. Grouping conventions

Identifying groups of matched tool marks was an important consideration. When two casts were matched they were assigned a letter, presuming of course that they did not appear to fit into a pre-existing group. The sets of casts produced are described as '**core groups**' as they provide the firm basis for further examination (chapter 10)

A simple lettering code was adopted for the groups established. Starting at A and working forward until the end of the alphabet at which point the next group was AA. When first grouping the casts the woodchip assignments were kept separate using codes WA, WB and so on. In retrospect a simple sequential assignment would have been sufficient. By applying the codes strictly sequentially it is easy to ensure that no two groups accidentally get assigned the same code. The letters act as an accession code for the casts belonging to that group and it is easy to establish the nature of the members of a particular group from the database.

A group code was also given to timber bearing facets that allowed for a complete signature to be established, through the presence of both side 1 and side 2 on the piece and a complete jam curve. This allowed for the possibility of including in the groups timbers that did not have signatures but on which tool shape was clearly defined.

9.3.2. Combinations and permutations

The comparison of casts can be a lengthy process if taken to its logical extreme. For a data set of 250 pieces of wood the number of matches to be considered is 31125 (i.e. $250*249/2 = 31125$); as this data set increases the number of combinations increase exponentially. For 1000 data items, for example, the number of combinations would be 499500.

While these figures appear daunting there are ways in which the work load might be reduced. In particular it has been found extremely useful to examine casts in small sub sets. Thus, facets from closely associated timbers are examined before matches are sought amongst the entire data set. Experience has shown that this has the effect of amassing the greatest number of groups from the least number of comparisons. Rapid group formation reduces the overall number of comparisons required. Further casts are compared against the group as a whole rather than a series of individual casts

The choice of these subsets might be based on apparent features or merely on spatial criteria. In the current project, casts were examined in the following groups: the extension feature, the off-site feature and piles in the organic material according to their excavation area (e.g. all the piles cast in B2 were examined together). By examining clear features first groups are formed which may then be looked for amongst material where the nature of the structure is not clear.

The principle that comparisons can be made against groups of casts as well as individual casts is important. It allows for the possibility that rapid on site assessment can be made. By producing amalgamated cast groups such as portrayed in the next chapter, newly found signatures can be rapidly compared with all previously found sets.

CHAPTER 10

The core groups

The following chapter outlines the results of the comparisons between the cast signatures collected from Oakbank Crannog. Basic groups of timbers are presented whose manufacture is associated. These associations are described and points about each group are represented. The distribution of each group is discussed and the blade width for each axe is demonstrated wherever possible (see also table 10.1).

A series of figures illustrates each of the groups of matched facets (figs.10.1 - 10.31). Specific features discussed in the text are highlighted within each of the illustrations (F1,F2, etc.) and the timber number for every cast is listed down the right hand side. The black arrow next to each cast number indicates the position of the pile point in relation to the signature orientation.

Each set of matched facets discussed in this chapter is described as a **core group**. These are accumulations of signature matches about which there is no doubt. Examinations of the matches between the facets in the figures can be enhanced by tilting the top of the page downwards and looking along the illustration

10.1. Core groups from the extension feature.

All sixty of the timbers in this feature are driven into loch bed silts and piles could, therefore, be examined without disturbing the surrounding stratigraphy. The extension also had the advantage of having been well sampled during Dr. Crone's dendrochronological study of alder from the site (chapter 16).

The timbers were assessed by excavating around their circumference until faceted surfaces were exposed. By using a powerful underwater torch, at a shallow angle to the wood surface, any signatures present could be highlighted. Once signatures were noted a single cast

of the widest mark present was taken. In addition any other facet in the exposed area was cast if it appeared that it had a different signature pattern.

Although only a single cast was taken from each timber it enabled groups to be formed. From these groups, decisions could then be made as to which timbers would be raised for additional examination.

Group A (fig.10.1)

Description.

This group consists of nine separate timbers from areas B6, B7, C7, D7 and D6 (fig.5.2 & 10.32). They form part of the extension feature defined by Dr. Dixon in his original thesis (Dixon,1984b). The key visual characteristic of this group is a triple peak toward the centre of the blade, F1 in figure 10.1, which makes it an easy signature to recognise even underwater.

All representatives of this group fit extremely well and there is no doubt that the production of the facets examined was conducted by the same axe. In all but one case the links are so good that it is considered unlikely that any resharpening phase has occurred during the production of the nine timbers.

The production of the timbers in this group represents a considerable number of blows. Piles 1035, 1047 and 1050 have been raised and are currently in wet storage. Examination of the remnant facets on these pieces revealed evidence of 120, 109 and 115 blows of the axe respectively. These figures are likely to be representative of the other members of the group that have not yet been raised. The facets remaining on a particular timber do not represent the actual number of blows used in the production of that piece. In the Somerset Levels it was estimated that in the production of a small stake tip between 50 and 60 blows were required leaving 5 or 6 recognisable facets (Coles & Orme,1985,27). Experimental work conducted during this project also suggested that this was the case. The working of a pile, of similar dimensions to 1050, could require 700 blows or more. Consequently, the production of the

timbers represented in group A could in reality require well in excess of 6000 blows. It is, therefore, all the more remarkable that the marks left on all of these timbers are so similar.

The facets on pile 1047 demonstrate a slightly different pattern. In particular the left hand ridge of F1 is very faint on this timber. As the rest of the features on the facet appear very similar to those on the other casts it is clear that resharpening is not the cause of this difference. It is, however, possible that the rest of the members of this group represent a signature with subtle extra damage. Consequently, it might tentatively be proposed that pile 1047 was produced before the rest of the timbers in the group.

A further feature that can be noted in this group is the direction of strike. In most cases the axes strike direction is toward the point. In two cases (Piles 1014 and 1054) the direction of working is reversed. This is quite a common situation and a small number of the facets, on all the timbers raised, run counter to the general direction of working. Often this is related to the removal of the remains of side branches or knots.

Blade dimension.

A complete blade dimension is available for this group as well as a reconstructed blade edge. This shows an axe with a curving edge that is 58 mm wide (See section 11.1). The blade reconstruction is derived from two facets on pile 1035 from which the jam wood has been removed; features on these two facets were linked by overlapping signature elements. It should be noted that while both sides were present, the complete curvature was not. However, enough of the curve remained to accurately postulate the shape of the small part of the blade not present; the missing part is highlighted in figure 11.1 by a dotted line.

Dendrochronology.

Six of the timbers within the group have been looked at dendrochronologically (X12A,1035,1047,1050,1052,1054). They range in age between 21 years (1035) and 44 years (X12A) and in diameter between 12 cm and 17 cm. Only three of these timbers are

linked to others dendrochronologically. The terms used in the description of these associations are based on the work conducted by Dr A. Crone in 1988.

Dr. Crone's work is discussed more fully in chapter 16. Some basic terms used in her thesis will be introduced here as they demonstrate the manner in which the timbers are associated in her work. **Blocks** refer to sets of timbers that have a good visual match between their tree ring patterns. The **traditional chronology** refers to a sequence produced by matching together the average of the curves from each block. The **Sort.String chronology** refers to a technique of computer assisted curve matching, developed by Dr. Crone; the method examined the whole data set for consistent sets of inter relationships (see section 16.2). The latter approach produced slightly extended and sometimes differing results from those produced by the traditional method. Neither of the chronologies ^{is} ~~are~~ absolute and represent a range of years defined by the oldest and the youngest tree represented in the chronology. Thus, arbitrary year 0 in each chronology is defined by start of growth of the oldest timber and the final year in the chronologies is defined by point at which the youngest timbers ceased to grow. It is the visually matched blocks that Dr. Crone considers the most reliable.

Pile 1035 is to be found in block 17 (Crone,1988,fig.59) and is placed in year 84 of the floating traditional chronology (i.e. it ceased to lay down rings in year 84) (see chapter 16, fig.16.1). It has also been placed in year 47 of the floating Sort.String chronology. Pile X12A is to be found in block 18 and is placed in year 43 of that block. Block 18 has not been tied into the floating traditional chronology but the occurrence of a member of group A in this block neatly links it to block 17. Pile 1050 only occurs in the floating Sort.String chronology and is placed in year 70.

The two piles in the floating Sort.String chronology (piles 1035 and 1050) are placed some 23 years apart. The tool mark evidence so far points to 1050 being incorrectly placed in the final Sort.String chronology. This situation is discussed more fully in chapter 16.

Distribution (fig.10.32)

Group A is distributed almost all the way around the extension feature¹. Its broad distribution would suggest that the axe was used to produce piles during the primary construction of this feature. If this group represented replacements it would imply that the originals were removed before the driving of group A timbers. Such removal is both difficult and unlikely. The confusion of timbers that exists within the main mound clearly indicates that additional construction was conducted without the removal of older uprights (see section 16.3.1). It may be significant that there is very little overlap between the distribution of this group and that of group B (see chapter 14).

Group B (fig.10.2)

Description.

Members of Group B are located within areas B6 and B7. The signature is very fine but all members of the group are considered to be firmly associated. Its key characteristic is the close set double ridge with a third fine ridge set slightly to the right (F1). It should be noted that this feature is superficially similar to F2 in Group A. The widths of the axes used in these two groups are clearly different and the similarity between features is thus coincidental. This illustrates that additional features need to be sought before a match is accepted. In the case of group B two additional features help confirm the connection. Two larger double ridges are located to the left of F1 and are present on facets from piles 1016,X12,1025,1023 and 1000 (F2,F3). On the facets from piles 1012,1017 and 1001 it is a series of finer striations to the right of F1 that confirm the match.

No obvious differences can be seen between the various members of this group. The facets on pile X12 are clearly affected by erosion, to a higher degree than the rest in the group, and subtle differences are lost along with the finer detail. There are additional details surviving on the other members in the group, suggesting an episode during which extra damage occurred.

¹ Note that more than one core group can occur on the same pile, the implications of this on the interpretation of distributions are discussed in chapters 12 - 14.

The facets on piles 1025 and 1012 appear to show an extra ridge just to the right of F1. It may be suggested, therefore, that these facets were produced after the rest in the group. However, caution should be exercised when observing fine ridges as these may easily disappear through differential erosion of the timber surface or indeed may less readily be registered in every swing of the axe.

Blade dimensions.

As this was one of the largest groups so far defined it was considered important to attempt to fully reconstruct the blade shape. None of the piles brought up during the 1990,1991 or 1992 seasons displayed this signature and a brief sampling trip was therefore organised in 1993 to extract an example of this group. Fortunately, the pile extracted (1012) has allowed the reconstruction of the complete blade width and shape. The axe that produced the group has a width of 66.5 mm with a gently curving blade.

Dendrochronology.

Three members of this group have been looked at dendrochronologically (1017,1025,X12) they range in age from 26 to 50 years. Pile X12 has not been fitted into any of the diagrams but piles 1017 and 1025 both occur in year 49 of block 19. As this block has not been fitted into either of the floating chronologies it is not possible to determine how this group fits with the rest of the extension feature dendrochronologically.

Distribution (Fig.10.32)

This group has a restricted distribution. Most of the group falls into square B6. A number of the piles are quite close to each other and eight of the timbers appear to form two relatively straight rows (1000,1001,1012,1013 followed by 1016,1017,X12 and 1023). The close spatial association of these timbers may suggest that the time between the working of piles and the driving was minimal. The possibility does, however remain that they were being drawn from discrete sets of worked timbers produced prior to a building episode (see chapters 14 & 16). The lack of clarity of the pattern produced by the piles in this area makes it difficult to

see exactly how this group relates to the rest of the extension structure. Beyond pile 1026 the structure of the extension becomes much clearer.

Group C (fig.10.3).

Description.

This group contains six timbers located in squares B7, C7 and D6. The characteristics of this group are clear and easily identified. The principal features are a thick ridge (F1) with a smaller double ridge to its left (F2). F1 and F2 are present on all the facets although F2 is somewhat obscured on the facet from pile 1026. A third smaller ridge (F3) clearly also links the four uppermost facets in figure 10.3. The link between all of these timbers is excellent and the associations can therefore be used with confidence.

Despite the excellence of the fits it can clearly be seen that there are a number of subtle differences between the facets cast; in particular attention should be drawn to the cast of a facet on pile 1039. The dulling of features that can be seen on this cast is an excellent example of poor replication; if there is too little pressure between the casting material and the wood surface the film of water between the two becomes such that it is recorded on the cast as a smooth surface. This does occur to some degree in all situations but it is rarely possible to see its effect by eye; SEM photographs clearly show this quality at magnifications beyond x200 (Plate 9.2)

The features on the facet from pile 1051 also appear dulled, although lack the glossy appearance of the cast from pile 1039. If compared with the cast from 1028, F2 appears somewhat flattened. The pitted texture displayed by this cast is usually a good sign of subtle erosion of the surface.

F2 appears to vary from one facet to the next. A good example of this is the difference between the cast taken from pile 1038 and some of the other facets. In 1038 this feature can almost be described as a single ridge, lightly scored down its centre, while in all other cases,

with the exception of the facet from pile 1039, this is not the case. Possible sources of the difference include mechanical variations at the time of production or modifications of the blade's edge due to use over time.

The cause of the differences discussed above may be traced to the position of the blade relative to the direction of force that results in a **variation in inter-ridge distance**. This effect would tend to merge the two ridges of F2. The facet from 1039 represents this possibility. Examination of F3 clearly shows that the signature is more compressed than other members of the group. By comparing the distance between F1 and F3 on the facet from 1039 to that on 1040 it is clear that compression has occurred. This is also clear when comparing the distance between F1 and F2 on 1039 and 1040.

The facet cast from pile 1038 also appears to show a slightly different form of F1. The large F1 ridge is clearly less pronounced on this facet than that observed amongst the other members of the group. Such a difference can also, however, be observed amongst the facets on the raised pile 1051. This suggests that these differences result from variations in striking angle or force rather than resharpening or extra damage.

Some of the other ridges also appear to be more pronounced in some facets than in others. In particular examination of F3 on the facet from pile 1026 shows it to be larger than that found on any of the other facets displaying the same feature. This facet also displays a number of features that are not clearly defined on the other facets particularly in the area between F1 and F3. It is difficult at present to explain this difference. Extra damage could be regarded as the cause, which would imply that this facet was late rather than early in the sequence of pointing that produced this set of timbers. This may also apply to facet 1028, which displays extra damage to the left of F2.

Blade dimensions.

One member of this group has been raised (Pile 1051) but it has not been possible to reconstruct a full blade width or curvature. The minimum width of the blade for this group is 51 mm.

Dendrochronology.

Three timbers in this group have been looked at dendrochronologically (1038,1040 and 1051) they range in age from 25 to 32 years. They have all been placed at year 35 within block 17 and at year 84 of the traditional floating chronology. Pile 1051 is also placed using the Sort.String approach (Crone,1988,fig.78,year 33) and within the Sort.String floating chronology at year 47 (Chapter 15, fig 15.5). It should be noted that members of groups A and C are both placed in the same basic block at the same felling year.

Distribution (Fig.10.32)

This group has a relatively wide distribution and is part of the well-defined area of the extension feature. It is a useful group as it links the production of the piles for the inner ring with those of the outer. Spatially, five of the timbers are closely associated in two groups. Piles 1026 and 1028 are located next to each other in square B7 while piles 1038,1039 and 1040 are also very close to each other.

Group D (fig.10.4)

Description.

This group contains two timbers located in squares B7 and C7. The key characteristics of this group are straightforward and are easily recognised even underwater. Two principal features are present the double ridge to the left of the facets (F1) and the single ridge to the right (F2). Fainter features are present and would enable matches to be made when one or other of the main features were not present. In particular a fine triple ridge is present on a number of facets (F3).

The facet from pile T1 clearly shows a number of very subtle features. These features are not clearly seen in the cast of a facet from pile 1045. The latter facet shows the lightly pitted appearance of a slightly eroded facet surface. In particular F3 is very difficult to detect on the cast from pile 1045.

Blade dimensions

Pile 1045 was raised as one of six timbers used during a pilot study into signature examination (Sands,1989). It demonstrates that even when the complete timber is raised further information may not always be forthcoming. On all facets with signatures on this piece the same basic features could be noted. However, although side 1 features were present and partial jams existed a complete blade pattern could not be constructed. Little more information was gained from the whole pile than from the single cast from T1. The maximum width so far established for this group is 47 mm.

Dendrochronology

No dendrochronological work has been conducted on either member of this group.

Distribution (fig.10.33)

This group belongs to what might be considered as the outer ring of the extension feature and is part of a very clear structural pattern. They are separated by six intermediate piles and by a straight line distance of over five metres.

Group E (fig.10.5)

Description.

This group contains two piles in areas B7 and C7. The signature is very fine and it would be impossible to establish a match without casting. That it may be a sub area of another signature has been considered but at present none of the other groups appear to fit. No set of

features on this signature appears more important than any other. Indeed it is the link between so many fine details that make the association between these two piles so certain.

Blade reconstruction.

Neither of the members of this group has yet been raised and none of the facets exposed during excavation revealed side features. The signature is thus not yet fixed to a particular part of the blade. Despite this it is possible to say that the blade that formed these facets was no smaller than 49.4 mm.

Dendrochronology

No dendrochronological work has been conducted on either member of the group.

Distribution (fig.10.33)

The two piles in this group are members of the outer ring of the extension feature. They are separated by four piles and a straight-line distance of 4.5 metres.

Group F (fig.10.6)

Description.

This group contains two piles located in square B6. The link between the two piles is excellent. A key feature of the link is a broad band of damage (F1) to the left of the side 2 feature. The presence of side 2 on both facets further confirms the certainty of this link as it fixes the position of both signatures on the original blade.

Blade dimensions.

Neither of the piles in this group has been lifted and full blade definition has not been established. The minimum blade width is 50.5 mm.

Dendrochronology.

Both the members of this group have been looked at dendrochronologically and the number of rings is 35 (Pile 1004) and 33 (Pile 1005). Both have been placed at year 42 of block 18. This block has not been placed in the traditional floating chronology.

Distribution (fig.10.33)

The distribution of this group is restricted. They are situated next to each other and their centres are only 25 cm apart. Their proximity to the main mound could suggest that they supported a different part of the crannog structure and were not directly associated with the extension feature. However, they appear to form a regular line with piles 1002,1003 and 1007.

Group G (fig.10.7)

Description.

Six piles are now clearly seen to make up the this group located in areas C7, D7 and D6. Facets from five of these piles are illustrated in figure 10.7. The key feature of the facets shown is a prominent ridge with a series of smaller ridges on either side (F1). Although a number of the representatives of this group appear slightly eroded the link between all of these timbers is excellent. Features F2 and F3 are clearly important but are only clearly registered on the facet from pile 1056. On the other casts in this group these features have either been eroded or are only faintly recorded. Recently a single facet on pile 1051 has shown to clearly link with features F2 and F3 although F1 is not present on this facet. The facet on pile 1051 demonstrates that F3 is just to the right of a side 1 feature. The proximity of these features close to edge of the axe could be one explanation for the variability in the signature registration. The gently curving shape of many of the axe blades could result in features towards the centre of the blade being registered more clearly than those on the extremities. The nature of this group and the new association is further discussed in chapter 12.

Blade dimensions

Two piles have been raised but it has not been possible to make full width or blade reconstructions for this group. The minimum blade width is 51.7 mm.

Dendrochronology

Six piles from this group have been looked at dendrochronologically. The number of rings on these piles ranges from 21 to 31. Four of these have been placed in diagrams. Piles 1035, 1056 and 1058 have all been placed at year 35 of block 17 and at year 84 of the traditional floating chronology. These piles are also all placed in Sort.String diagrams (Crone, 1988, fig. 78, year 33) and are located in the Sort.String floating chronology at year 47. Pile 1050 is only placed in the Sort.String floating chronology and is assigned to year 70.

Distribution (fig. 10.34)

All of this group, except 1035, is distributed along the south side of the extension feature. The connection of pile 1058 with the construction of the extension feature is uncertain as it is so close to the piles of the main mound. The signature association proves beyond doubt that it is associated with the construction of the extension feature.

Group H (fig. 10.8)

Description.

This group includes two piles located in area B6. A thick flat ridge is the principal feature of this signature (F1). A number of finer ridges also match; note for example the feature denoted by F2. The facet on 1008 appears eroded. This is the reason for the slightly fainter appearance of all the features on 1008.

Blade dimensions.

Neither of the timbers have been raised and a full blade curvature is not available. However, side 2 registration is present on the facet from 1008, which fixes the position of the

signature for subsequent comparisons. The combination of the two facets gives a minimum blade width of 64.1 mm.

Dendrochronology.

Neither of these timbers have been examined for dendrochronology.

Distribution (fig.10.34)

These piles are found in proximity to each other, on the shoreward side of the extension feature. Like the piles in Group F it is not clear how these piles relate to the extension feature.

Group I (fig.10.9)

Description

This group includes four piles located in areas B6 and C6. The principal feature of this signature is a thick ridge (F1). A second feature, linking all four facets is just apparent on the extreme left edge of all the casts (F2)

The link between the facets is good although the facets from 1006 and 1007 seem to have suffered slightly from erosion. This has had the effect of giving a flattened look to the top two facets. The flattening of F1 has removed the groove apparent along its length in the casts from 1010 and 1055.

The distance between F1 and F2 on the facet from pile 1055 is greater than the rest of the group. This effect has already been discussed; it should be noted, however, that this not only increases the distance between ridges but also extends the width of individual ridges. F1, for example, is wider on the facet from pile 1010 than it is on the facet from pile 1055.

Blade dimensions

None of the timbers in this group has been raised and no edge or jam features are present. The minimum blade width is 53.2 mm.

Dendrochronology.

Piles 1007 and 1010 have both been placed in dendrochronological diagrams. Pile 1010 is placed in traditional block 18 at year 42 (Chapter 16, fig.16.2). It is not placed in the traditional floating chronology but does occur at year 47 in the Sort.String floating chronology. Pile 1007 is not placed in a traditional block but does occur in the Sort.String floating chronology at year 68. The apparent discrepancy between the placing of these two piles in the Sort.String chronology is discussed more fully in chapter 16.

Distribution (fig.10.34)

Piles 1006,1007 and 1010 are all relatively close and are situated on the shoreward side of the extension feature close to the main mound. Like groups F, H and I these piles are not a clearly defined part of the extension feature. Pile 1055 is located almost directly opposite this group on the other side of the extension feature. The position of 1055 might appear to confirm the role of the other three piles in the support of the extension structure.

Group J (fig.10.10)

Description

This group includes two piles located in B6 and B7. The main feature is a broad ridge (F1). F1 in combination with a number of fine features ensures the positive identification of a match between these two facets. As there is so much fine detail present no resharping is envisaged between the production of one facet and the production of the other.

Blade dimensions.

None of the timbers in this group have been raised and no edge or jam features are present. The minimum blade width is 63.5 mm.

Dendrochronology

Pile 1003 has been examined dendrochronologically and is placed within block 18 (Crone,1988,fig.60). This block has not been placed within the traditional floating chronology for the site but is placed at year 47 in the Sort.String floating chronology.

Distribution (fig.10.34)

These two timbers are located on the shoreward side of the crannog, amongst the area of the extension feature in which the form of the construction is confused. It is thus difficult to decide how this group may have related to other groups, such as group A, which form part of the clear semicircular double alignment of posts (see also comments for groups B, F, H, I)

Group K (fig.10.11)

Description.

This group includes three piles located in area B7. The link between 1030 and T2 is excellent as shown by the F1 feature as well a number of finer ridges. The association between 1034 and the other two timbers is definite enough to be included in this group but the link is not as good as many others. No key characteristic stands out in this group and it is not possible to identify this link without casting.

Blade dimensions.

None of these timbers has yet been raised and a full width and blade curvature is not yet available. The minimum blade dimension for this group is 40 mm.

Dendrochronology.

No dendrochronological examination has been conducted.

Distribution (fig.10.35)

The timbers are all part of the outer ring of the extension feature.

Group L (fig.10.12)

Description.

This group contains two piles located within area C7. A number of quite fine features link these facets and the signature is hard to identify underwater (F1 and F2). The link between them is, however, excellent and no significant differences can be identified between the facets.

A feature of this signature, more readily observed, occurs on the secondary facets of the cast from 1049 and consists of a set of three ridges (F3). The distance of F3 to F1 is defined by the presence of F2 on both the lower and upper facets represented on the cast from this pile.

Blade dimensions.

Pile 1049 has been raised and a complete blade width and blade shape have been reconstructed. The maximum blade width is 53.5 mm.

Dendrochronology

No dendrochronological examination has been conducted on this group.

Distribution (fig.10.35)

The two piles in this group are located close to each other (some 2m apart) and lie on the outer ring of the extension feature.

Group M (fig.10.13)

Description.

Group M consists of four piles located in square C7. The signature is very fine but the principal feature is a double ridge toward the right of the facet (F1). The link between these three timbers is excellent and no particular differences between the signatures on each can be noted. It is likely that this group is the product of the same axe that produced group A. The

marked features in figure 10.13 are probably the same as F1 and F2 in Group A (see chapter 12).

Blade dimensions

Pile 1051 has been raised. Both side features were present and thus a minimum blade width value could be calculated. A complete blade curvature was not, however, forthcoming as only partial jam features were present. The minimum width is 49.8 mm.

Dendrochronology.

All the timbers in this group have been looked at dendrochronologically. Piles 1042 and 1051 are placed at year 35 in block 17. Pile 1043 is placed at year 36 in block 17. Pile 1036 by contrast is placed at year 46 in block 17. In the floating traditional chronology they are located at 84 (1042,1051), 85 (1043) and 95 (1036) years. The one year discrepancy between three of the timbers is discussed in chapter 16 and is related to physiological factors in the growth of alder. The 10-11 year discrepancy between pile 1036 and the rest of the group is also discussed more fully in chapter 16.

Piles 1043 and 1051 have been placed in the Sort.String chronology at 48 and 47 years respectively. This group is linked to the same year of felling as groups A, C and G.

Distribution (fig.10.35)

The distribution of all four piles is restricted. They all fall on the inner ring of the extension feature.

Group N (fig.10.14)

Description.

This group contains two piles from areas D5 and C6. There is no key characteristic that defines this signature and it is difficult to identify underwater. Although the signature is fine

the link between the cast facets is excellent with even the finest ridges matching up. F1 and F2 indicate the principal points of match.

Blade dimensions

Pile 1744 has been raised and a full blade width and curvature have been reconstructed. This group is remarkable both for the breadth of the blade used (79.1 mm) and for the apparent stratigraphical differences between the two timbers. The latter factor is discussed more fully in chapters 14 and 16.

Radiocarbon Dates

Pile 1744 has been radiocarbon dated. The calibrated results for this sample can be found in appendix A.

Dendrochronology

Pile 1060 has been looked at dendrochronologically. It is located at year 34 in block 17. This places its position in the traditional floating chronology at year 83. It is placed within the floating Sort.String chronology at year 44. The significance of this association is considered more fully in chapter 16.

Distribution (fig.10.36)

Although this is a small group the placement of its timbers is significant as it potentially links two parts of the crannog structure. Pile 1060 occurs at one end of the extension structure while 1744 appears to be related to the supports of the main building.

Group T (fig.10.15)

Description.

This group contains piles located in areas B7, C6 and C7. A single ridge is the key feature but a series of very fine ridges provides the confirmation of the link.

Blade dimensions.

Pile 1036 has been raised and the complete blade width is 57 mm.

Dendrochronology.

Pile 1036 has also been examined dendrochronologically. It has 30 rings and has been placed in year 46 of block 17. In the traditional floating chronology its final ring is placed at year 94. This should be contrasted with other timbers in block 17 that are placed 11 or more years before this.

Distribution. (fig.10.37)

All the timbers in this group are part of what can be regarded as the inner ring of the extension feature. Pile 1059 is located close to the main crannog mound whilst piles 1032 and 1036 are amongst the double row of posts away from the site to the west.

Group W (fig.10.16)**Description.**

This signature has so far been found on only one pile but is included as both sides of the axe are registered on its surface. The pile is located in area A5 and has been considered as part of the extension feature. Although this pile has been raised its signature has not yet been shown to link with any of the groups established for this feature.

Blade dimensions.

This pile has been raised but it has not been possible to reconstruct the blade curvature. The presence of both side features allows a close approximation to the true blade width. The minimum blade width is 61.4 mm.

Dendrochronology.

Its position within the piles of the extension feature and its lack of association with other timbers may suggest that it was placed at a different time from the rest of the timbers in that

area, possibly as a repair. As yet there is no evidence to prove this assertion and no dendrochronology has been yet been conducted on this timber.

Distribution.

Pile 1018 is located on the shoreward side of the extension feature.

Group X (fig.10.17)

Description.

This group contains two piles located in areas B7 and C7. The key feature is a single ridge but a series of fine marks confirms the association. The signature on pile 1046 is less obvious than that on 1035. The feature F2, for example, is not present on 1046. This is considered a result of surface erosion rather than a resharpener episode as most of the other fine ridges are still present.

Blade dimensions.

Both of these pieces have been raised but no complete blade width has been established. The minimum blade width is 40 mm.

Dendrochronology.

Both timbers have been looked at dendrochronologically and both have 21 rings. Pile 1046 has only been placed in Dr. Crones' Sort.String diagrams and is placed at year 45 in the Sort.String floating chronology. Pile 1035 has been placed by both approaches. In the traditional approach it is placed in block 17 at year 35, which is year 83 in the traditional floating chronology. In the Sort.String approach it has been placed at year 47 in the floating chronology, which is two years after the position of pile 1046. This is well within the potential error noted by Dr. Crone for alder trees (see chapter 16).

Distribution.(fig.10.37)

Both piles occur on the inner ring of the extension feature.

10.2. Core groups from the main mound

All areas that have been investigated on the main mound were examined for material with signatures. There are many piles in these areas but unfortunately not all of these had faceted surfaces available for examination. A minimal amount of localised excavation enabled some timbers to be cast and matched. These are discussed in the following sections and serve to show that the piles within the main mound will be a fruitful source of signature information as more excavation is conducted on the site.

Group O (fig.10.18)

Description.

Only one timber represents this signature located in area C1. It has been given a group code because it has a clear signature and can be fully defined; blade width and shape have both been reconstructed. This timber is unusual as it was found lying on its side within the organic layers of the site. The pile was apparently reused as a chopping block. How soon after the pointing episode this occurred is not clear.

Blade dimensions.

The axe that was used to form this point was one of the smallest so far discovered being only 45 mm wide.

Dendrochronology.

No dendrochronological work has been done on this piece.

Distribution

The pile was located in area C1.

Group S (fig.10.19)

Description.

This group contains three piles located in areas A3 and A4. The key characteristic is a bold ridge in the centre of the axe, with three finer ridges to the left (F1).

There is no significant difference between the facets other than slight dulling through erosion. The group is interesting for the sources of information. Pile 710 was cast underwater on the site in 1992 and remains in-situ. Pile 495 was raised in 1981 and has been in storage, in water tanks, at the Scottish National Museum, in Edinburgh, until June 1993. Pile 505 was conserved with PEG in 1982. Despite the different sources the link between the signatures is obvious and can be relied upon.

Blade dimensions.

Piles 505 and 495 are available for full examination. Pile 505 has provided the evidence for complete width determination and full blade shape. The maximum blade width is 45 mm.

Distribution. (fig.10.38)

All three timbers in this group are quite closely associated and may originally have formed a straight line. All are or were contained within the organic material of the main mound and are surrounded by many other piles.

Pile 505 has been placed within a feature defined by Dr. Dixon, during the early stages of excavation at Oakbank. Feature 6 is one of the largest proposed pile groupings and is regarded as possibly being part of the outer wall of the house and/or inner walkway supports.

Group U (fig.10.20)

Description.

This group contains two piles located in area B3. Key features include the bold quadruple peaked ridge to the right (F1). The association between these two piles is definite and the link persists even to the finest details.

Blade dimensions.

No piles have been raised in this group and full blade definition will have to await further excavation as both piles are imbedded in organic material. The minimum blade width is 58mm.

Dendrochronology.

Pile 379 has been looked at dendrochronologically and has 46 rings. It is placed within block 4 at year 46. In the traditional floating chronology its final ring is placed at year 83. This is the same year as the majority of the extension timbers found in block 17.

Distribution. (fig.10.38)

The two piles are located close to each other along the shoreward boarder of square B3. Pile 379 is identified by Dr. Dixon in his original feature assignments. It has been placed in feature 4, which has been described as the central part of a door post structure related to the main entrance.

Group V (fig.10.21)

Description.

This group contains two piles located in areas B3 and A4. The signature is good and the association between these two timbers is assured. No obvious difference is apparent between the two facets and no resharpener is envisaged.

Blade dimensions.

No piles have been raised in this group. The minimum blade width is 46.2 mm.

Dendrochronology.

Timber 421 has been looked at dendrochronologically and has been positioned at year 33 in block 7. This block has been placed within the traditional floating chronology and timber 421 has a felling date of around year 82. This is a year before the bulk of the timbers in block 17 but due to physiological reasons the felling year could be the same (see section 16.3). The curve produced from the measurement of 421 has also been directly linked to individual curves of timbers in the extension feature (Crone,1988,fig.65). In this diagram it falls into the same felling year as piles 1056,1057,1058, and 1051.

Distribution. (fig.10.38)

The piles in this group are both located within the a mass of piles that form a bewildering array within the organic material of the main mound; although only a small group their position does link together information from two areas excavated in different years. The association of these two piles is not apparent and may not have been considered without the signature evidence. All the visible piles in this area have been looked at during this study but unfortunately many of them do not yet have accessible facets. However, there is a very high chance that future excavation will extend this group and possibly give a clearer picture of the structural feature to which these timbers belong.

10.3. Core groups from the off site feature

The off site feature is a line of twelve piles that run at right angles to the causeway close to the shore. All the timbers in this group have been cast and all have signatures. The function of this feature is still uncertain but it may have ensured that direct access to the site was by the

causeway only. Any attempt to approach the site by water would have had to go around this feature.

Group P (fig.10.22)

Description.

This group contains four piles located in an area away from the main site. The key characteristic is a set of bold ridges (F1).

No significant differences between one facet and the next can be noted. Thus resharpening phases between the productions of these piles are not proposed. The hair line score marks running across the signature on the facet from 1748 are a product of weed growth down the timber surface. In some cases this can lead to the signature becoming indistinct. This weed growth is most notable amongst piles embedded in the silt and located closest to the shore (e.g. piles 778,779 and 780).

Blade dimensions.

Pile 1748 has been raised but at present a full blade definition is not forthcoming. The minimum blade width is 51.5 mm. A side 2 feature is present for this mark so the signature's position can be absolutely fixed on the blade.

Radiocarbon dates.

Two radiocarbon samples were taken from pile 1748, the calibrated dates for these samples can be found in appendix A. The dates fit with the rest of the site and signature links may be found that will associate the construction of the off-site feature to a particular phase of building on the main mound.

Dendrochronology.

No dendrochronological work has been done for this group.

Distribution (fig.10.39)

These piles are part of a roughly linear feature running parallel to the shore. The distribution of this group within the off-site feature adds little to its general interpretation particularly as there is a strong physical association between this group and other signatures within this feature.

Group Q (fig.10.23)

Description.

This group contains two piles both from the off-site group. The key feature of this group is the thick ridge with a finer ridge to its left (F1). The signature is somewhat underrepresented in the facet from pile 1758 but the association with 1748 is clear.

Blade dimensions.

Pile 1748 has been raised but a full definition of this blade is not yet possible. The minimum blade width is 39 mm.

Dendrochronology.

No dendrochronological work has been done on either of these pieces.

Distribution. (fig.10.39)

The comments made for Group P also apply to this group.

Group R (fig.10.24)

Description.

This group contains four piles forming part of the off-site group. The signature is fine and key characteristics are hard to establish.

The facet from 1748 is somewhat different from the rest in the group. The bolder features that can be noted on the right of the facets (F2,F3) appear narrower on the facet from pile

1748. Resharpening can be rejected as a cause on the following basis. If the other finer features on all the facets are examined it can be seen that these are still present. Had resharpening occurred to an extent that it removed the bolder features the finer features would also have been removed. An alternative is extra damage after the production of 1748 and this may well be the case. However, differential erosion after deposition cannot be ruled out especially as the finer ridges of 1748 reflect the pattern of bolder ridges in 1751. Note should also be taken of the fact that there is some weed growth on this timber.

Blade dimensions

Pile 1748 has been raised but at present a full blade reconstruction is not possible. The minimum blade width is 62.7 mm.

Dendrochronology

No dendrochronological work has been done on this piece.

Distribution. (fig.10.39)

The distributions of the timbers within this feature are not particularly informative at present. The occurrence of all three groups on pile 1748 suggests that all the timbers in groups P, Q and R were produced by the same axe (see section 12.3.4).

10.4. Core groups from woodchip material.

Woodchips are regularly found within the organic material of the main mound and several hundred have been sampled since the beginning of the Oakbank excavations. The groups discussed here have been formed after examining the 150 pieces that were selected from the original sample. As many of the smaller woodchips have only fragmentary signatures superficial similarities may be observed but the veracity of the associations is difficult to prove unless the ridges have clear shape similarities (e.g. group WF) or there is a sufficient quantity of fine detail (e.g. Group WG). Groups WH and WI represent woodchips from

which full blade shape can be reconstructed; no signatures are, however, available for these groups.

Group WA (fig.10.25)

Description.

Four wood chips make up group WA and were all found in 1990 in area A2. The signature association between these woodchips is excellent and there is no doubt that they were the product of the same axe. No significant differences can be noted among these four and the time between production is considered minimal.

All four of these chips are larger than the majority of those looked at during this project. The smallest in the group is 6 x 5 x 0.5cm (5014) while the largest is 22 x 11 x 5.7cm (5070).

Blade dimensions

A complete edge curvature is available for this group (from chips 5070 and 5047) and gives a maximum blade width of 57.5 mm.

Distribution.

All the chips in this group come from a zone within one metre of a line running from the A3 to the B3 datum. Chip 5070 is specifically located close to the B3 datum around the end of the jointed timber (1581). 5047 and 5142 were from the same sample bag and come from along the west side of the jointed timber.

The four chips in this group span three context assignments. Chip 5047 comes from context 007 that is described as being : 'soft sawdust-like material containing some bracken and fern mostly very broken up'. Chips 5047 and 5142 are from context 009, which is an : 'organic matrix of bracken and fern with some comminuted plant material' and which underlies context 008. Chip 5070 is from context 012, which has been described as a: 'deep/soft organic layer containing many cherry stones and nuts' this context underlies context 011. Both contexts 008 and 011 have been described as a lens of fine silt and sand. The different

context assignments may reflect the short lived nature of many of the contexts rather than a mixing of stratigraphy.

Group WB (fig.10.26)

Description.

This group contains two woodchips that were both found in 1990 in area A2. The connection between the two is good with even the fine detail matching. No resharpening episode is proposed for this group.

Blade dimensions.

Both chips are very small and neither indicate of the form of the blade used. The minimum blade width is 33 mm

Distribution.

Both chips come from context 009 located close to the line between datum points A3 and B3.

Group WC (fig.10.27)

Description.

This group contains two woodchips that were found in 1990 in area A2. Although the photograph suggests that the connection between these two is based only on two closely spaced ridges, finer features also confirm this association.

Blade dimensions.

Although a small jam feature is present on chip 5011 there are no side features and it has not been possible to reconstruct the original blade edge. The minimum blade width for this group is 33.5 mm

Distribution.

Both chips were found within context 007 (see group WA) along the west side of the jointed timber (1531).

Group WD (fig.10.28)**Description.**

This group contains two woodchips and one pile. The woodchips were found in 1990 in area A2 while the pile is located in area C1 and was cast in-situ in 1992.

The link between the chips is firm while the association with the pile is considered highly suggestive but not perfect.

If the link between the pile and the woodchips proves to be true, it suggests that 1652 was cut after the production of the woodchips. The features on the pile appear smaller and a resharpener episode is indicated. To prove this assertion 1652 will have to be raised and examined to establish a full blade definition to compare with that produced for the chips.

Blade dimensions.

It has been possible to fully reconstruct the blade edge used in the production of chip 5002. This reconstruction gives a maximum blade width of 57.5 mm.

Distribution (fig.10.40)

The two chips both come from context 007. The pile (1652) is located some 6m away in area C1. If this association proves to be correct it demonstrates the manner in which the manufacture of uprights might be associated with certain stratigraphic horizons.

Group WE (fig.10.29)

Description.

This group contains two woodchips; both were found in 1990 in area A2 and were part of context 009 (see group WA). This group is interesting as it provides an example of a groove on the signature (F1). Groove features are produced by projecting metal on the blade edge that gouge out wood from the facet surface rather than leaving areas upstanding as produced by the gaps on a damaged blade.

A further point to be noted about grooves is that they may be specific to a particular orientation of the blade. A backhand swing will produce a slightly different signature to a forehand stroke. In one case the bend in the metal will be swinging into the wood gouging out material, while in the other it may be away from the wood surface and act like a normal gap in the blade. Experimental work during this project demonstrated this principle using both a modern and a bronze axe.

Blade dimensions.

Neither chip has the features to produce a full blade reconstruction but the minimum blade size for the axe used is 31 mm.

Distribution.

Both chips were found in area A2.

Group WF (fig.10.30)

Description.

This group contains four wood chips found in area B1 in 1988. The signature represented by these three woodchips is easily recognised. There are some differences apparent between the facets on the woodchips. It is suggested that 5118 was produced sometime after the rest in

the group based on the extra damage that appears to be present on 5088, 5117 and 5122 (e.g. F2).

Blade dimensions.

No jam or side features are available for this group so it is not possible to reconstruct the edge of the axe used. The minimum blade width for this group is 39 mm

Distribution.

These chips were recovered from area B2. Chip 5088 is assigned to context 004. Chips 5117 and 5118 are assigned to context 004/004b while 5122 is placed within 004b.

Group WG (fig.10.31)

Description.

This group contains two woodchips both found in 1990 in area A2. The signature on both is good but limited. The association between the two is assured by the links in the finer detail.

Blade Dimensions.

Neither of these chips has edge or side details remaining and the minimum width for the axe used is 37 mm.

Distribution.

The woodchips in this group come from two contexts 007 and 009, these are both discussed in relation to group WA.

Group WH

Description.

This woodchip does not possess a signature. It is a large chip of elm wood upon which blade curvature and edge registration is clearly defined. The maximum width of this tool is 51.5 mm. Although no signature is present the excellent definition of the blade allows for

positive exclusion from other groups and possibly the inclusion of this chip into a group that does have a signature.

Group WI

Description.

The woodchip in this group was found in 1988 in area B1. It is included because a complete blade reconstruction can be established. The width of the blade is 56.5 mm.

CHAPTER 11

Tool reconstructions and exclusive tests.

The previous chapter discussed the character of the core groups established for the timbers so far sampled. The following chapter discusses the manner in which the blade width and shape of some of the axes from Oakbank Crannog have been reconstructed from tool mark details. In particular a technique is introduced which uses signatures to combine information from different facets. From the reconstructions it is possible to positively exclude unplaced casts from certain core groups.

11.1. The reconstruction of complete blades

When all tool mark features are found together on a single facet it is an easy task to fully define the axe blade and shape. The removal of the jam, to reveal the jam curve, and the observation of both side features in relation to the curve clearly illustrates the form of the original blade edge (see chapter 2 and glossary). However, these features rarely occur on a single facet. Most facets retain only one or two of these features. To retrieve the complete blade definition from timbers with only partial tool marks it is necessary to combine information from different facets. To do this accurately requires a technique called **signature combination**.

Signature combination involves examining a timber, or sometimes more than one timber, from a group, for a set of facets that display overlapping parts of a blade's signature. At its simplest this may only involve two facets. The first retains a side 1 feature, a portion of the jam curve and one side of the signature. The second facet has a side 2 feature, the other part of the jam curve and the rest of the signature. The right hand part of the first facet and the left hand part of the second record the same area of the axe; the signature allows the two halves to be placed together with accuracy. In some cases the process may involve three or more facets to link a side 1 feature to a side 2 feature. However, in all cases, the principle is the same;

different facets are linked by common signature elements. Figure 10.16 illustrates this principle. In this figure the minimum axe width for group W has been calculated by combining information from two different facets

On some timbers there may not be enough jam features to record full blade shape. In these cases the blade width can be estimated using signature combination and side features alone. However, clearly, without the presence of the curve feature the width of the tool is likely to be underestimated. This is a consequence of the fact that a blade edge may not travel through the timber at right angles to the direction of force, this brings the ridges and side features of a facet closer together (see Chapter 2). Without the presence of the jam curve it is difficult to assess the extent to which the width is underestimated. When the jam curve is present it clearly indicates the orientation of the blade and the width can easily and accurately be determined.

To quantify the discrepancy discussed above some accurate measurements were made on selected facets. Pile 1744 (Group N, Chapter 10) provided a good subject as a complete blade curvature was available against which to test estimates based on side features alone. Dendrochronological equipment was used to accurately measure the distances between facet features. It was established that the distance produced for the blade width using signature combination and edge registration alone was 7.34 cm. This compares the true measurement for the blade width of 7.91 cm. In other words the edge estimate based on side features alone was approximately 93% of the real blade width.

A question that arose from the above examination was whether the ratio between the real and the estimated widths remained constant. If this was found to be the case then blade width measurement could be reconstructed solely using side features and signature combination; from this estimate adjustment could be made using the established ratio to determine the true blade width.

The close link between many of the marks within individual groups described in chapter 10 suggested that a constant error might be present. To test whether such an error was being produced a number of other marks were examined in a similar fashion to that which had been conducted for group N. However, it was found that the ratio was not sufficiently consistent between groups to allow for reliable adjustment of width estimates without jam curve features. On pile 505 (A member of Group S), for example, the real width of the blade is 4.5 cm and the apparent width from the use of side features is 4.51 cm. The apparent width is approximately 99% of the real width and a ratio clearly different from that noted on Pile 1744 (Group S). Other estimates also demonstrate a range of differences. Pile 1582 (Group O) had an apparent width that was 99.67% of the true width while pile 1012 (Group B) was 89.83% of the real blade dimensions. The latter gave an error in the estimate of width for Group B that was more than 6 mm below that of the true axe width. No variation has yet been established that exceeded the latter example but it demonstrates that blade width figures that lack full definitions have to be treated with caution. It should be noted, however, that the estimates produced solely using side registration and signature combination will never exceed that of the true width of the blade.

11.2. Blade reconstructions at Oakbank.

The Oakbank material has so far revealed ten fully defined axe blades (fig.11.1). At least six of these are clearly the product of different axes with both their widths and to some extent their curvatures varying. The possibility that some of these reconstructions may be the product of the same axe is discussed in the next chapter.

The blades vary in size from 4.5 cm (Groups S and O) to 7.91 cm (Group N). The extent to which these blade attributes fit with known archaeological finds is discussed more fully in Chapter 15. All the axes have gently curving edges; blade shape is also considered in more detail in chapter 15.

11.3. Axe blade widths and exclusive tests.

The use of accurately reconstructed blade widths is a key way in which groups may be shown to have been produced by different axes. If two groups are shown to have clearly different widths they are unlikely to have been produced by the same axe and certainly will not have been produced by the same axe during the same phase (see below).

The width and shape of an axe's blade will, however, change with time. There are three ways in which such changes might occur:

- Breakage.
- Resharpening.
- Edge hammering.

Breakage and a series of resharpening episodes would result in a reduction of width while edge hammering would potentially result in an increase.

Clearly alterations in the width of the axe are unlikely to retain signature information. Certainly extensive resharpening to the stage that the blade width alters will be signature destructive. Breakage might allow for some signature survival but is likely to result in major adaptations of the signature form. Consequently, looking for differences in blade width enables the number of cast comparisons required to be reduced. It is clear that whether blade reconstructions with different widths are regarded as different axes, the fact that the width has changed make it highly unlikely that any signature match would emerge.

The width of an axe is a relatively robust feature and major alterations will take some time to occur. Consequently, within a single phase of construction, such as the extension feature, different blade widths will clearly reflect the use of different axes.

Axe width reconstructions can be used to exclude unplaced casts from the comparison process. The facets represented by these casts may be fragmentary and may show no facet features other than a signature. The exclusive test involves searching the database for all

casts that have a facet width greater than the blade reconstruction chosen for comparison. Table 11.1 shows the use of the test for the axes so far reconstructed from Oakbank. The table lists all the cast facets in the database that have a width greater than that recorded for the reconstructed blades. Each of the Oakbank blades has been placed in the table at a position that indicates their width, all cast facets listed below these positions will have been produced by different blades; for small axes such as S & O just over a quarter of the database could be excluded from the comparison process using this technique. Such exclusive tests could be very useful when much larger data sets are considered.

CHAPTER 12

Establishing links between core groups.

The previous chapter demonstrated the manner in which the shape and width of a tool could be reconstructed from the combination of facet features. Using the complete blade reconstructions it was possible to demonstrate that different core groups were clearly the product of different axes. This chapter explores the possibility that some of the core groups established in chapter 10 are the product of the same axe.

12.1. The principles

Although core groups are the product of individual axes it is possible that the same axe will result in more than one group. There are three main ways in which the use of the same axe can be missed:

- Core groups can be formed using only part of a tool's signature. It is, therefore, possible that two groups could exist that are merely representative of different areas of a particular blade. This is especially likely amongst woodchip groups where the number of facets on a single item is minimal and where only small fragments of a signature survive.
- A signature will change over time. Extra damage and repeated resharpening will produce alterations in the signature. Consequently, a single blade will have a whole sequence of signatures during its working life. Different core groups may thus merely represent different members of the same **signature set**.
- Work during this study has also suggested that signature registration can vary. Although a tool will predominantly produce the same signature its pattern will occasionally be registered differently. This occurrence is most clearly seen in the matches between core groups A, G and M (discussed below). The reasons why this should occur are not fully understood; strike angle, accuracy and fitness will all be variables. Although it is difficult

to determine the precise reasons for the variation in any given situation, the occurrence of registration variation can often be identified when different signature groups are found on the same timber (see below)

There are three lines of evidence that can help in identifying when different core groups belong to the same signature set:

- Core groups that have the same blade width and curvature.
- Core groups that occur on the same timber.
- Core Groups with a degree of signature similarity.

These three lines of evidence provide the basis for the links between the core groups discussed below.

12.2. Groups associated by similar blade widths and curvatures.

On the Assendelver Iron Age farmstead, 20 km west-north-west of Amsterdam, edge shape alone has been used to suggested the number of tools used to work the tools examined. In this work fourteen tool marks were characterised, amongst these a certain number were considered to have been produced by the same tool. Although signatures were present on some of the timbers they did not occur in sufficient numbers and consequently the association between tools was made on the basis of similar edge form rather than an obvious signature link (Therkorn et. al., 1984,365).

Although blade width and shape are good indicators that the same tool has been used some caution is required before firm statements are made. Edge shape and width can be similar from one tool to the next. This is particularly likely if the site being investigated was built using bronze tools. Casting of axes from the same mould can lead to very similar blade widths and curvatures. Standardisation toward the end of the bronze age can also be argued. A good illustration of this possibility is provided by the finds of Late Bronze Age socketed axes within Northern Britain and Scotland (Schmidt & Burgess,1981; see also chapter 15). Of the 700 or more socketed axes recorded from this area over 340 examples have blade widths between 40

and 50 mm. While early iron axes were forged rather than cast their widths and blade shapes can also be very similar (see chapter 15).

Similarities in blade form do, however, focus attention on possible associations, when the signatures are also examined resharpening episodes or occasions when extra damage has occurred can be identified. The following sections discuss two such possibilities amongst the core groups from Oakbank crannog.

12.2.1. Groups WA and WD

The clearest example of the manner in which tool marks in two different core groups have been matched together on the basis of blade reconstructions is to be found between groups WA and WD. Both of these groups have identical blade width and shape reconstructions (see fig 11.1)

It was clear that groups WA and WD represented different stages in the life of the same axe. Many of the fine details of both groups coincide but there are some major differences. In particular additional damage can be observed in group WD. For this damage to have been present first it would have to have been sharpened out for it not to appear in group WA; in other words as sharpening removes fine detail more quickly than coarse detail the fine detail observed in the match would not be present. It is thus very clear that the production of chip 5002 (Group WA) occurred after chip 5070 (WA) (Plate 12.1).

12.2.2. Groups S and O

Groups S and O might also be suggested to be the products of the same axe. The width of the axe blades used to produce these two groups is identical. However, there are no clear similarities between their signatures and the locations of the timbers in each group might instead suggest the use of different axes that merely have similar blade attributes.

The timbers that form Group S are all in-situ piles. Two of the members are located close to each other in area A3 while the third member is also close in A4. Pile 1582 (Group S) by

contrast is located on its side amongst the upper layers in area C2. It is uncertain whether it was ever used as a pile and if it was to which phase it belonged. Despite uncertainty as to its original role, 1582 has clearly been reused as a chopping block.

It appears that pile 1582 came to rest in its present situation quite some time after the piles in Group S were driven. This fact does not preclude the use of the same axe in both groups. Indeed, the time gap is a good explanation for the difference in signature observed.

The blade shapes of these two groups are different. The axe that produced group S is more bowed than that which produced group O. If these were the product of the same axe it suggests that the group O blade has become flattened through repeated resharpening. This is, however, very difficult to prove.

The only manner in which O and S might be positively linked to the same tool is if intermediate signature forms were found during future excavation. As a signature changes through resharpening each successive stage should link with the previous one, unless the signature is very fine in which case it could be rapidly altered, perhaps within a single sharpening phase. The connection between signatures of each successive stage of sharpening could link two otherwise unconnected core groups. The complete life record of an axe is, however, unlikely to be found. Fire wood collection, tree felling and a number of other activities may not be reflected on the timbers preserved on a site. Furthermore, it is rare for a structure to be completely preserved. At Oakbank, for example, much of the superstructure no longer survives.

12.3. Links between groups found on the same timber.

A physical link between tool marks is an important way in which relationships between core groups can be clearly indicated. Different core groups may, for example, be found on the same timber or on different timbers that have been jointed together. However, this

relationship need not necessarily imply the use of the same axe and each situation needs to be considered separately to establish the reason for the association.

12.3.1. Groups A, G and X

The discovery that more than one core group existed on the same pile was first noted on timber 1035 (fig 12.1). On this timber it became clear that while facets with group A signatures predominated there were also a number that clearly demonstrated group G type signatures and those of group X. Of the 120 discernible facets left on the surface of pile 1035 some 60 clearly belong to group A, 21 to group X and 7 to group G.

The reasons why different core groups should be found on the same timber are not immediately obvious. The different possibilities can be summarised as follows:

- The use of more than one axe.
- The use of the same axe altered by resharpener or extra damage.
- The use of the same axe but the registration of different parts of the blade.
- Variable signature registration resulting from differences in axe use.

The use of more than one axe could be established by reconstructing the blades of all the groups to see whether positive differences could be noted. However, amongst these three groups only those facets produced by group A had enough features to recreate the full blade form; while groups G and X had partial jam curves there were not enough facets to produce useful reconstructions.

In addition to pile 1035 groups A and G also occur on piles 1047 and 1050. That three piles bore the same pairing of two core groups did not preclude the use of different axes but, if the groups were the product of different axes, it suggested a very systematic approach to pile production. It would imply that one axe was doing the general pointing while a second added the finishing touches.

The presence of Groups A and G on more than one pile did suggest that if they were the product of the same axe the differences seen were unlikely to be the result of resharpener or

extra damage. It could be argued that when resharpening or extra damage occurs the change from one signature form to another will be registered only once, if at all, during the working of a single timber. In other words, as the pile was being produced, the worker paused to resharpen the axe and the work then continued with the adapted signature. The pattern of association between the two signatures would not be expected to reoccur on three separate piles. It is true that the three piles mentioned above could have been worked to a certain stage, the axe resharpened, and then all three piles finished off with the same axe. However, while the latter could occur it would seem unlikely.

The possibility that the facets from each group merely represent different parts of the same blade can be clearly discounted. The full blade shape and width are fully defined for group A. The blade width of this axe was 58 mm. It is clear that many facets from both G and X would have considerable overlap with those of group A.

The most likely conclusion to the associations between Groups A, G and X is that they were all the product of the same tool resulting from slight mechanical differences between strokes. This would account for consistent association between groups on different piles. The implications and further evidence of this assertion are discussed more fully in sections 12.5 and 12.6.

12.3.2. Groups M and T

The raising of pile 1036 in 1993 demonstrated clear registration of both Group M and Group T, an association that has subsequently also been found on timber 1051 (see next section). The width of Group M is very similar to that of T and thus if the same axe was in use it was not merely registration of a different part of the blade. Similarities between the signatures of the two groups are apparent. This fact combined with the similarity in width suggests a variation in registration and thus the use of the same axe in both cases (see section 12.5)

12.3.3. Groups C, M and T

The discovery of more than one core group on a timber occurred again in the case of groups C, M and T; these were clearly associated through pile 1051 (fig.12.2).

Both edges were registered for axe M; giving a blade width of 48.9 mm. The width so far established for group C is 51 mm. It has already been pointed out that width reconstructions based only on side features can underestimate the true width of a blade; consequently, this size difference is not sufficient to positively prove the use of a different axe.

The signatures of groups C and M have clear differences. The main bold ridge of group C (F1,fig.10.3) was clearly not present on group M. For this to be the same axe it must be envisaged that group C was the result of extra damage or group M was the product of extensive resharpening.

None of the timbers so far extracted have allowed for a full blade definition for either group. To prove that C and M were indeed the product of the same axe would require the extraction of additional members of each group until full blade definition could be established. This principle is illustrated by groups WA and WD above.

Group T was also found on this timber. It seemed that this was a variant of group M, a connection that will be demonstrated in section 12.5.

12.3.4. Groups P, Q and R.

Pile 1748 has facets that represent three signature groups. None of these groups have complete blade reconstructions and it has been difficult to absolutely establish the relationship between them. However, it is clear that group Q is a manifestation of the axe that produced group P (Plate 12.2). The wide solid ridge in group Q is a registration of the broad multiply peaked feature in group P. The distribution of these three groups on timber 1748 is illustrated in figure 12.3.

The relationship between group R and the other two groups is harder to determine. Group P has a width of 51.5 mm while group R has a width of 62.7 mm. If this signature represents a different part of the blade a very broad tool is suggested, potentially over 110 mm. The use of a broad bladed tool on a small pile such as this one is likely to register incomplete parts of the signature; the blade being wider than the largest faceted surface that can be produced. It would seem unlikely that this pile has had two tools used in its production as its size is such that it would be easily and rapidly produced. Resharpening is a possibility but difficult to prove without full blade reconstructions.

12.4. Links between groups that have similar signatures.

12.4.1. Groups H, I and J

These three groups represent an example of a situation where a set of groups appear to be variations of the same signature. Groups H and I fit convincingly together while group J appears similar to group J (Plate 12.3)

Examination of the signature details of groups H and I reveal much in common. Pile 1008 of Group H has a side 2 feature. An accurate measurement was taken between a known point and the edge feature and this was then repeated on cast 1003 (Group I). The feature chosen for the measurement was the wide ridge that is suspected of being common to both groups (F1 in figures 10.8 - 10.10). If the measurement on 1003 was substantially greater than that on 1008 the two axes could be argued to be different. The results showed no significant difference. The measurement for group I was 40.485mm and that for H 39.640mm. The difference of 0.845mm is well within the variation in inter-ridge distance noted for other axes.

The similarities among these three groups appear too strong to have occurred by chance and it is almost certain that they do in fact represent the same axe. As such it is tentatively suggested that Group J represents a light resharpening of the axe.

12.4.2. Groups A and M

The discovery of a number of facets that reflect these two groups has clearly demonstrated that they are forms of the same signature. This is a connection about which there is very little doubt. Although it is clear that the two groups are the same it is not so clear why the differences have occurred (see section 12.6).

12.5. Signature similarities - demonstrating group amalgamations.

The associations above indicate some interesting possibilities. In particular if all the group connections that are suggested to be the result of the same axe prove to be correct a major grouping of timbers is indicated.

Groups A, C, G, M, T and X are all possibly the product of the same axe. As seen above these connections, with the exception of that between A and M, have been suggested by their occurrence on the same timbers. A, G and X all occur on timber 1035, M and T on timber 1036 and C, M and T on pile 1051; when examining these groups it was not immediately clear why these associations occurred (see above for discussion of possibilities). However, careful examination of various casts suggested that different signature registration from the same axe was the most likely explanation.

Plates 12.4 - 12.7 show the manner in which signatures of the six core groups might be seen to fit together. The plates show a set of associations that give examples of the most convincing fits. Not all the core groups convincingly fit with every other core group. However, in all cases it can be argued that they each have a connection with at least one other group in common. It can be seen, for example, that C and M are argued to have some signature similarities. This is demonstrated most clearly by the following association (Plate 12.4):

104002 (C) + 103603 (M)

This connection is not clearly apparent amongst any members of group A. However, because it can be shown that group M and group A are indeed the product of the same axe it may therefore be argued that, if both associations are true, groups C and A are the result of the same axe.

Plate 12.5 illustrates the clear connections between the G, M and A core groups. This is expressed in the following **association sequence** (see glossary):

$$105601 (G) + 104201 (M) + 103603 (M) + 101401 (A)$$

Group G may, thus, also be argued to associate with group C. Group T is argued to associate with groups G and M through the following association sequence (Plate 12.6):

$$103601 (T) + 105601 (G) + 104201 (M) + 103603 (M)$$

Because of this sequence Group T can also be argued to match with A.

Group X can be suggested as matching with group A and, therefore, by inference with groups M, G, T and C. The association sequence for this match is (Plate 12.7):

$$103501 (X) + 103512 (A) + 101401 (A)$$

Some of the associations described above may be regarded as weaker than others. In particular some scepticism might be aroused by the suggestion of a link between M and C. It is clear that there are some major differences between these two casts not least of which is the bold ridge that forms such a major feature of groups C. Likewise groups X and A are not as tight a link as others observed. However, in both cases these marks are found on the same timbers. This fact combined with signature similarities adds considerable weight to the argument that they are different manifestations of the same axe edge.

Of the other connections suggested there is little doubt that groups A, G, M and T are all members of a single **signature set** (see glossary).

12.6. Resharpening and extra damage.

The last section has suggested that a number of the core groups from the extension feature represent different aspects of the same axe. The logical extension of this observation is to consider whether any of these association might be explained in terms of resharpening or extra damage. In other words can a broad chronological sequence be suggested for the production of the timbers. The following section discusses a possible relative chronology for the production of the piles produced by the axe represented by the amalgamated group A(C,G,M,T,X).

It is often difficult to prove that damage or resharpening has occurred. It has already been demonstrated that a single axe may produce variations of its signature merely as a result of differences in its use. This is best demonstrated by the fact that groups A and G both occur on piles 1035, 1050 and 1047. Core groups A and G are clearly the product of the same axe and the fact that they pair up on three occasions strongly suggests variation as a result of differences in the use of the axe rather than sharpening or extra damage. Other associations, however, more clearly suggest resharpening or extra damage.

If the connection between C and M is accepted, then it is clear that Group C was produced after that of M. If the bold ridge was present before the production of group M it would have to have been completely sharpened away to produce the form observed in Core Group M; if this had occurred no underlying similarities between the two signatures would be expected to survive. By contrast, if group C was produced after Group M the survival of underlying similarities might be expected. The extra damage incurred might result in a sharpening phase but it would be too wasteful of metal to attempt to completely remove the gap that produced the bold ridge. The axe would function perfectly well with the damage unless a smooth finish was the objective. In the production of pile points smooth surface finish is clearly not a consideration.

A sharpening phase might be conjectured between core groups A and M. It is tentatively suggested that M is produced after that of A. The features in group M that correlate with those in group A are marginally reduced in size and subtle extra damage is apparent.

If the above is correct the following core group sequence is suggested:

$$A(G, X) \rightarrow M(T) \rightarrow C$$

The distribution of the piles does not suggest this sequence; however, as it is unlikely that the piles would each be cut just before driving no pattern would necessarily be expected. The implications of this are considered more fully in chapter 13.

A set of experimental marks demonstrates some of the characteristics of sharpening and extra damage. All the marks in plate 12.8 have been produced using a replica Bronze Age socketed axe based on a find from Killin, at the west end of Loch Tay. The first cast in the sequence represents a mark produced when the blade had been dulled through use. A tree felling and pile pointing sequence were part of the work that had been conducted as well as a number of other smaller tasks. Subsequent casts represent marks produced after three resharpening phases.

The second cast in plate 12.8 represents a resharpening phase sufficient to produce a keen edge. It is clear that this resharpening phase did not destroy the signature. Indeed there appears to be remarkably little effect. The main difference after the resharpening was that the cutting action was more effective and the ridges of the signature were consequently more cleanly registered. The third cast shows the signature after the next resharpening phase. This was slightly more extensive to produce as sharp a blade as possible. More differences are apparent between this cast and the second one than between the second one and the first. However, the link between the two casts is still clear. Of particular note is the persistence of the fine detail to the left of the signature. These features are closest to the edge of the axe. It is apparent when resharpening the axe that the centre of its curved edge tends to receive more

sharpening than the edges. Consequently, the features in the centre of the blade will incur more changes than features at the extreme edges of the blade.

The final cast in the sequence demonstrates extra damage. This was produced unintentionally when the axe bounced off the wood surface and struck a small stone on the ground. These casts perhaps mimic the events that occurred between the production of group M and group C. When the damage had occurred the edge was not broken but was bent. The rest of the blade was not dulled to any significant degree and work could have continued. However, the damaged area projected from the blade edge and the removal of the extra metal seemed logical. Consequently, a light resharpener followed the damage event to maintain the effectiveness of the blade. Despite damage and resharpener it is clear that the underlying signature does not disappear and a match with the previous phase is clear. However, the pattern has changed over the three resharpener episodes; examination of cast two against cast four clearly demonstrates these differences.

The precise number of resharpener episodes required to remove a signature is not easy to determine. It is apparent that resharpener phases that are merely maintaining a keen edge do not remove large amounts of metal and the pattern of the signature can persist. Consequently, there is perhaps more variation between signatures as a consequence of variations in use or the nature of the wood (species type and grain orientation) than there is between signatures of sequential sharpening episodes. It is, however, apparent that over five to seven sharpening phases of the bronze replica that the signature could change to a significant degree. The alteration of a modern steel axe signature is far less rapid and can persist over considerable amounts of work and resharpener (see fig.1.1).

Experimentation throughout this project has so far suggested that signature change is difficult to quantify absolutely. Heavy handed resharpener can destroy a signature in a single episode while very careful resharpener can allow the pattern to persist over a number of episodes. Furthermore, it is also clear that different people maintain their axes to different standards, some may maintain a perfect edge all the time while others might allow the tool to

become slightly less efficient before resharpening. All of these factors make it difficult to establish an experimental method that could produce clearly applicable results. Having said this, however, it is unlikely that a signature will survive unchanged for more than a few days during extensive use.

While the persistence of a signature is difficult to establish, it is clear from the Oakbank material that the same pattern is surviving over a period that is sufficiently extensive to allow a useful number of timbers to be associated. In addition by reconstructing blade shapes and looking for the occurrence of different core groups on the same timber it is possible to considerably extend the number of timbers that can be linked to the use of a single tool. This information will also enable aspects such as extra damage or the occurrence of resharpening to be identified. As more and more timbers are examined from the site some of the questions that have not yet been adequately answered by experimentation may be answered by the material itself. As further groups are established it may, for example, become apparent that any given core group never exceeds more than a certain number of similarly sized timbers. From this it should be possible to postulate the minimum number of blows over which a particular pattern is surviving.

CHAPTER 13

Aspects of construction

The previous two chapters have demonstrated the manner in which blade edges can be reconstructed and core groups shown to be the product of the same tool. From this information it is possible to start making some comment as to the number of axes employed in making a particular structure. As the extension feature is the most heavily sampled this provides the basis for the following discussion.

13.1. Estimating the number of axes used.

To start to accurately define the number of axes used during construction, structures or features within a site have to be isolated that clearly indicate relatively rapid construction. If rapid construction is not certain or if a proposed structure potentially spans two building phases then estimates could be inflated. Off site work in the interim and/or the production/purchase of new axes can all lead to a division between the apparent number of axes used and the number of workers that that figure represents.

The most suitable feature for estimating the number of axes used is once more the extension structure. This is not only the most heavily sampled but has also been shown, both through signature links and dendrochronology, to have been built within a single constructional episode.

The extension feature contains 65 piles of which 55 have clearly been placed into one or more core groups. The 55 piles can be divided into 17 core groups which represents the absolute maximum number of axes used to produce the piles. It is clear from the discussion of core group amalgamations in the last chapter that the actual number of axes used to produce this feature is far fewer than 17.

Examination of the core group amalgamations leads to the conclusion that there are a maximum of 10 axes involved in the building of this structure. These are as follows:

- ❶ Group A(C,G,M,T,X)
- ❷ Group B
- ❸ Group D
- ❹ Group E
- ❺ Group F
- ❻ Group H(I,J)
- ❼ Group K
- ❽ Group L
- ❾ Group N
- ❿ Group W

Of these axes numbers 1,2,8 and 9 have all been fully defined and are clearly different. The rest demonstrate only incomplete parts of the blade and, thus, it is possible that some may prove to be the product of the same axe when more piles are raised. While this is the case a consideration of the amount of work done by each group gives a much clearer suggestion of the number of axes that were major contributors to the construction of the extension feature. The most prolific producer of piles is group A(C,G,M,T,X), of the 55 piles placed in core groups just under 44% have been produced by this amalgamation. Even when the weakest association, that of group C, is removed this amalgamated group still represents over 32% of the work. The next largest group is B conducting just under 17% of the work, followed by H(I,J) (14.5%). These three axes alone account for just under 75% of the piles placed in core groups within the extension feature (fig.13.1).

Groups L and N have also been fully defined and are clearly different from A(C,G,M,T,X), B and H(I,J). Thus, a minimum number of five axes is suggested in the construction of the extension feature. Four axes may be suggested as a minimum if axe N is excluded from the picture. Axe N has a very wide blade and does not appear to fit with any other pile within the main arc of the extension feature. The position of pile 1060, close to the

main body of the crannog, and the location of pile 1744 (also group N) within the deep pile group suggests that pile 1060 was not part of the same building sequence that led to the production of the extension feature.

13.2. Reconstructing the workforce.

It may be possible from the preceding discussion and the distribution of the piles to reconstruct some aspects of the workforce, possibly its organisation and its demography. Once again the extension feature provides a focus for discussion.

The first point to be made about the possibilities of reconstructing either of the above aspects of the workforce is that signature groups may not be equivalent to people. Up until now the ratio of axes to people has been considered as a one to one.

By suggesting that up to ten axes were used in the production of the extension feature it might be inferred that an equivalent number of people were employed in its construction. However, experience during experimentation has shown that hafts do periodically break. That this was also the case in the past is undoubted. It could be argued that workers spent time half way through a job to rehaft a tool but it is equally likely that this task was reserved for a spare moment at another time. Another tool would then have been used to carry on the work and two groups would appear on the finished timbers where only one worker was present. The consequence of this scenario is that group associations would provide an overestimate for the numbers in a workforce.

While the above might lead to overestimates there are situations that can lead to underestimates. If there were a limited number of axes then as one worker became tired another might continue the work with the same axe. Thus, the number of core groups would underestimate the number of workers involved. However, it could be argued that to a Late Bronze Age/Early Iron age crannog dweller the axe must have been one of the most essential pieces of equipment that could be possessed. Its use in all manner of operations from cutting

fire wood to construction may have meant that it was in almost constant use. The need to regularly borrow an axe would seem a less likely situation than the need to have a spare tool available.

Whether or not the axes, spare or otherwise, were considered personal or community items is conjectural and thus association of a signature to a particular individual cannot be proved. Having said this a suggestion has been made during the excavation of the Sweet Track, in the Somerset Levels, that facets distribution and chopping style may reveal the individual behind the work (Coles & Orme, 1984, 13). When combined with signature information and blade reconstructions the question of the representation of the individual may be confronted. Examination of facet distributions and chopping styles during the present study have not allowed for any firm conclusions. However, as more timbers are raised and more axe reconstructions produced a pattern may be sought.

In a rapidly constructed feature, such as the extension structure, it is highly tempting, and probably not erroneous, to equate tool groups with individuals. Examining the piles and their distributions from this point of view produces an interesting picture. The frequency and small number of axes used in the extension feature suggests localised effort rather than a professional group of builders.

A picture might be presented in which the building of the extension feature was the work of an extended family. There were potentially four key builders with some periodic help from other members of the family or community. One of these key builders was stronger than the rest and conducted most of the work while others, such as the person that used axe L, a fully defined axe, only produced two of the pile points. It is tempting to envisage that the small groups represent work conducted by youngsters learning the skills that will allow them to build their own structures while the large groups are produced by more experienced or stronger members of the household.

While the above produces a neat image of family co-operation there are other explanations for the observed patterns. The argument is based on the assumption that the distribution and number of timbers produced by each axe only reflects a single working episode that was solely intended to construct the extension feature. However, there is no evidence to suggest that this is necessarily the case. The extension feature is probably one element in a larger building program.

When the uprights were being prepared it could be suggested that it is most practical for the majority of work to be done close to the place of felling (Coles, J.M. et al., 1978, 29). Thus the lopping of the lower side branches and the pointing of the tip might be conducted shortly after the tree has been chopped down. If this work was done as closely as possible after felling the timber would be more easily worked and the amount of unneeded timber would be reduced before transportation. There is some evidence for this at the Late Bronze Age site of Cortaillod-Est, Lake Neuchâtel, Switzerland, where the pointing of piles at the felling site is suggested by abrasion marks caused by the dragging of the posts that obscure the facets of the point (Arnold, 1986, 90, fig. 91).

Whether the pointing of the piles was done close to the felling site or not it is unlikely that single piles were pointed and then immediately driven. It is more probable that there was a period of preparation prior to construction which resulted in a series of heaps of ready pointed piles on the beach. Each heap might mainly represent the work of one individual. When the time for construction arrived piles would predominantly be removed from a single heap unless a pile of a more suitable dimension was required. The uprights would therefore be driven in the order in which they were received from the stockpiles. Consequently, the distribution of signature groupings would not necessarily correlate with the organisation of the workforce that were undertaking the driving.

The use of timber from heaps of prepared piles might have led to a feature such as the extension, being predominated by one or two signature types. The distribution of core group

B might fit this pattern. The distribution of this group is restricted to one end of the extension feature. It could be argued that once pile 1025 had been driven the heaps which had included group B were exhausted and the heaps containing group A(C,G,M,T,X) started to be used. Furthermore, as group A(C,G,M,T,X) is almost entirely to be found on the inner ring of the extension feature it could be suggested that the heap from which those piles were being drawn was beginning to dwindle by the time the outer set of piles were being placed. The piles in the outer ring were either being taken from other heaps or quickly pointed by a group of people to make up for a short fall in the number of pre-prepared piles. This might explain the smaller groups which are found in the outer ring.

13.3. Social patterning - an alternative view.

The preceding discussion has concentrated on the practicalities of the construction process. It is worth considering, however, that the construction of a building may not only be based on practical considerations. This principle is excellently demonstrated by the author Herodotus writing in the fifth century BC when he speaks of a group of people, living over the waters in Lake Prasias, Northern Greece:

'Their manner of living is as follows: platforms supported upon tall piles stand in the middle of the lake, which are approached from the land by a single narrow bridge. At first the piles which bear the platforms were fixed in place by the whole body of the citizens; but since that time the custom which has prevailed about fixing them is this: they are brought from a hill called Orbelus, and every man drives in three for each wife that he marries. Now the men have all many wives apiece, and this is the way in which they live.' (Herodotus Tran. Rawlinson, 1992, 384, 5.16)

Herodotus was writing his work remarkably close in time to the possible date for the building of Oakbank and it demonstrates that, in some places at least, construction may have been culturally determined. It serves as a warning against the pursuit of rational twentieth century explanations of patterns found on archaeological sites. If the site in Lake Prasias

were ever found and examined it would be interesting to see if the signature groups only occurred in multiples of three.

CHAPTER 14

Signature Suites

The following short chapter discusses a principal that may prove useful in extending the recognition of spatial patterns amongst a confusing array of timbers.

14.1. The principle

The previous chapters have involved much discussion of whether different core groups were the product of the same axe. This discussion was of value in attempting to reconstruct workforce numbers, organisation and to some extent spatial patterning. However, there are a number of questions that can be addressed without the need to absolutely prove that two groups are the product of the same axe.

Many signatures can be positively identified with a single feature or phase of construction. This association is independent of the need to prove that the same axe was in use. The clearest example of this is when two core groups are found on the same timber. It can be argued that whether these two groups are considered as the product of the same axe they have a clear relationship. A similar argument can be put forward for timbers occurring within a clearly defined feature. In both cases a suite of signatures can be defined which represent closely associated working. If this collection of core groups is then found amongst timbers in a more confused area of the site they may be used to identify structural patterns.

There is always the possibility that reuse or later repair has occurred. This might lead to two or more signatures occurring on a single timber or within a feature that are not related. However, it is clear that the piling so far examined from Oakbank was not reused. All the uprights with signatures still have bark over much of their surface and give no indication of ever having been used for a different function. Furthermore, it is almost impossible to remove a structural pile once it has been driven. The issue of repair is a little more difficult to resolve.

However, by choosing very clear structure as the basis for defining signature suites such repair episodes should be identifiable.

14.2. Examples of signature suites.

The most obvious example of a signature suite are the marks found on the off-site pile alignment. This alignment is clearly the result of a single phase of construction and contains three well-defined core groups. There is a strong suggestion that these three groups are the product of the same axe (see chapter 12). However, while this is an interesting issue it is clear that all three groups are associated with a single brief building episode. In other words these core groups may be regarded as a **signature suite** for that phase of building. The consequence of establishing signature suites is that a greater number of piles can be included in a plot when looking for spatial patterning.

Although it has not yet been possible to use the signature suite principle at Oakbank a good example of the way in which it might be used is to be found in the extension feature. It is clear from this feature that many core groups can be associated. Leaving aside the confusion of timbers on the shoreward side of this feature the rest clearly represent a coherent and single phase structure. This fact is reinforced both by dendrochronology and core group distributions. Within this structure all signatures, including those not yet placed in core groups, can be utilised to define that phase of building. Thus the signature suite for the bulk of the extension feature can be regarded as follows:

Extension Feature Suite = Core Groups A,C,D,E,G,K,L,M,T,X

The previous chapter has described the manner in which some of these groups can be regarded as the same axe while others are clearly different axes; however, as noted above, for the purposes of signature suite construction such arguments are not important. What is crucial is that there is clear positive association with a single short lived event.

Clear features such as the extension or off-site pile group allow for a rapid building of signature suites. The power of this principal will become apparent when similar signatures are found on material from the main mound. The main crannog mound presents a confusing array of material and clear features are not often apparent. If elements of a previously defined signature suite are found within this mass of timbers they can all be plotted as part of the same phase to see whether structural patterns emerge.

The signature suite principle can also be used to extend small areas of clear structure that are found within the main body of the crannog. The best example of this possibility is the small row of piles defined by Dr. Dixon as feature 7. These potentially represent a wall division. They are clearly defined by the floor features (F17 and F24) and by the lack of other piles in the area (see fig.5.4). It is not apparent, however, how far the feature extends beyond this area. By casting all the piles that are clearly part of F7 it should be possible to establish the extent of the feature amongst the more confused material at its extreme ends. All these piles were examined during this study but while signatures should be present they are not yet exposed and further excavation in the area is required.

14.3. Signature suite resolution.

Signature suites can be resolved at different levels. At the most extreme a signature suite can be defined on the basis of a complete site. A site encompasses a discrete collection of timbers and signatures that all have some relationship to the construction of that site. Such broad signature suite definition enables questions, such as whether neighbouring structures had active interaction in building and repair, to be addressed.

At a smaller scale signature suites can be defined in a number of ways. The suite defined for the extension feature above does not, for example, include either axe B or axe N. This suite was chosen on the basis that there is some suggestion that axe B and axe N may be part of a different construction phase. However, while these groups may be part of different constructional episodes it is clear from dendrochronological work that the timbers used were

constructional episodes it is clear from dendrochronological work that the timbers used were all probably felled in the same year. Consequently, if different phases are represented they can be argued to have been separated by less than a year; as a consequence a signature suite could be defined that was based not on feature definition or signature distribution but rather on dendrochronological information. Subsequent finds of members of any one of these groups can legitimately be plotted together, without the need to await further dendrochronological measurements. The relationship between dendrochronology and signature connections is discussed more fully in chapter 16.

CHAPTER 15

Tool finds and the Oakbank axes.

In the late 1800's Dr. F.A. Forel suggested that, not only could the difference between the marks left by stone and those left by metal axes be distinguished, it was also possible that the form of a bronze axe could be assessed from the facets it produced. In discussing the oak and fir piles from the settlement site of Roseaux, Switzerland, Forel stated that:

'the cutting marks left upon them enabled us to decide that they were brought to a point by means of a spatula like celt or hatchet ... and not by the great bronze celt with ears.' (Keller, 1878, 300).

Forel's observations suggested an interesting line of enquiry: How do the marks found on timberwork from a site relate to actual axe finds? The following chapter explores this question for the reconstructed blades from Oakbank Crannog. The aim is to establish some of the possibilities and limitations of comparing axe marks with known tool finds.

15.1. The form of the Oakbank axes.

The only definite feature of an axe registered on the wood surface is the blade edge. As previously illustrated **signature combination** in conjunction with **jam curve** registration can result in a very accurate representation of the original blade edge (see chapters 2 and 11). Because of the unequivocal nature of the measurement derived from **side** and **jam** features, blade width is an ideal measurement for comparison against known axe assemblages. Ten axes have been clearly defined from Oakbank Crannog (fig.11.1). They are all relatively small tools. Group N is the largest so far found with a blade width of 79 mm while Groups S and O both represent a tool that is only 45 mm wide.

The shapes of the Oakbank blades were also clearly registered and it was felt that this aspect of the tools should also be examined. The edge curvature of all the Oakbank Crannog axes so far examined appears quite consistent. The extent of curvature can be expressed as

measurement of the distance between the centre of the blade and a line connecting the ends of the blade (Fig.15.1). Expressing this measurement as a percentage of the width gives a measure of the relative extent of edge curvature; the lower the percentage the flatter the edge. It can be seen that the figures derived from this calculation are quite uniform. The tool displaying the most extreme edge curvature is Group S (15.56%) while the flattest tool is that which produced groups WA and WD (6.96%).

The following sections introduce the tool find data and explore the similarities and differences between these and the Oakbank tools.

15.2. Axe finds - the nature and problems of the data sets.

15.2.1. Bronze Axes.

The construction of Oakbank Crannog appears to have occurred close to or shortly after the end of a period when bronze was the principal choice for the manufacture of edge tools. A large number of bronze axes have been found in Northern Britain and Scotland and they represent an extensive data set against which to test ideas about changes in dimensions over time.

The work by P.K. Schmidt and C.B. Burgess provided the basis for the examination (1981). This volume contains the bronze axes and hoards found in Britain, before 1980, north of a line running roughly from the river Mersey to the river Humber. Information about each tool from this work was typed into a database to allow for the recovery and identification of axes of certain dimensions. This enabled the axe widths, reconstructed from the Oakbank material, to be rapidly compared with known finds. In adding material to the database note was made of any axe with blade that was damaged either through breakage or corrosion and these were excluded from the final assessment.

The bronze axe data have been graphed and are shown in figures 15.2 - 15.9. The graphs display blade width in millimetres on the Y axis while the X axis shows the number of axes from the catalogue in each size category. Figure 15.2 shows the broader picture, all the axe finds from the Schmidt and Burgess volume are graphed according to broad chronological divisions; Early, Middle and Later Bronze Age.

The data gives the impression that there is increased standardisation toward the later part of the Bronze Age, with much smaller blades predominating the socketed axe types. The beginning of this process is perhaps masked by the grouping of a number of types, under the broad heading of the Middle Bronze Age. The reduction in width is apparent amongst the Later Short-Flanged axes (Taunton into the Penard phases) which are much closer to the distribution noted for the socketed axes (fig.15.2). The Later Short-Flanged forms average around 50mm in width, with a standard deviation of under 10mm while the socketed bronze forms have an average width of 49 mm with a standard deviation of just over 8mm (fig.15.3). Both of these dramatically contrast with the finds of Early Bronze Age flat axes that have an average width of 74 mm with a standard deviation of over 20 mm. The standardisation and blade width reduction towards the end of the bronze age may be mirroring other factors such as the introduction of leaded bronzes. The exact reason for this change is debatable but appears to be part of a trend that is found across Britain as can be seen in the graph for the socketed axes from the south west, which gives a very similar blade width range for socketed axes (fig.15.4; Based on Pearce,1983).

The restricted size distribution of the late Bronze Age axe widths gave some optimism for useful comparison with the Oakbank axe reconstructions. If the Oakbank tools could be shown to be larger than that expected for a Late Bronze Age axe it might suggest the use of iron tools on the site.

15.2.2. Pre-Roman Iron Axes.

The recovery and identification of pre-Roman iron working has been limited. This a consequence of reduced hoarding, the often poor survival of iron and the reduced recovery rate of iron objects as chance finds; iron being less visually inspiring than bronze and often covered by heavy corrosion products (Thomas,1989,265; Champion,1989, 293).

In Britain there is very little demonstrably early material (Darbyshire pers. comm.) and the report on the socketed iron axe from Maids Moreton, Buckinghamshire, remains one of the key sources of information (Manning & Saunders,1972 see also Rainbow, 1928). On typological grounds alone the iron socketed axe seems a natural contender as the successor to bronze forms. However, the forging in iron of a form intended to be cast demonstrates considerable iron working skills (Manning & Saunders,1972,280). Indeed this very fact has led Mackie to regard the socketed iron form from Traprain Law as a form of early marketing ploy by skilled iron smiths from elsewhere (MacKie,1971,64).

The lack of definite associations adds to the difficulty of placing these axes in any precise chronology (Manning & Saunders,1972,281). A find of a socketed iron axe in the lowest levels of Traprain Law in supposed association with Late Bronze Age material could suggest an early date for these tools if the stratigraphical information could be relied upon (Cree and Curle,1922). This perhaps supports MacKie's ideas that they are merely: 'one of the first tricks of persuasion' (Mackie,1971,64). However, although a rare find, the iron socketed axe has a wide distribution across Britain and Ireland. They have been found as far north as Gairloch, as far south as Wiltshire and as far west as Turoe, Co. Galway (Manning & Saunders, 1972, fig.2.). The data set has also been extended recently with the find of an iron socketed axe from the Fengate Power station post alignment (Coombs, 1992, fig.7.4). Despite the problems with the data set it seems fair comment that:

'the shaft-hole axe appears on present evidence to be a late introduction into Britain, the normal form for almost the whole of the iron age being the socketed axe' (Manning,1972,footnote 39,230).

Within Scotland five socketed finds have so far been reported (Manning & Saunders,1972, Nos. 10-13 & 19). Of perhaps most interest to the current study is the find in apparent association with a crannog site, in Bishops Loch, near Glasgow (Cree & Curle,1922,217 see also Stevenson,1966,21). Unfortunately, this find is now lost, its dimensions are unknown and its original relationship to the crannog site uncertain.

All the iron socketed axe widths have been graphed in the same manner as those for the bronze data set (fig.15.5). It is clear that, despite the limited number of axes that have been found, a greater range of blade widths are represented within the iron axe data than amongst the Late Bronze Age material. Consequently there is potentially some scope for separating Late Bronze from Early Iron Age tools on the basis of width alone.

15.2.3. Roman Axes and Beyond.

The current examination rests on the possibility that distribution of axe sizes at particular times is restricted to a particular range. Furthermore, that this range may be seen to change through time such that a find of a tool mark or set of tool marks on the margins or outside a particular range can suggest a chronological position or a shift in technology. If size ranges are broad or there is little alteration in tool kit forms over time the use of tool mark sizes may have little validity. Examination of Roman woodworking tools demonstrates a broad range of sizes and consequently dimensions are unlikely to be sensitive chronological indicators. Furthermore, it has been commented that:

'iron objects - especially tools - often show virtually no change in design over very long periods; indeed many Roman tools are identical with their nineteenth-century successors' (Manning,1972,228).

In consequence it was felt that the introduction of Roman technology provided a convenient cut off point for this investigation.

15.3. The Oakbank axes and axe find widths.

The series of graphs introduced above also display the widths of the complete blade reconstructions at Oakbank. These are displayed down the right hand side of the graphs as dashes, each of which is opposite the appropriate blade width value on the Y axis. Summary statistics for these graphs are displayed in table 15.1.

The graphs suggest that Early Iron Age tools have a greater blade width than the preceding bronze forms. Consequently, it could be suggested that if any tool width established from a timber exceeded 90 mm it would suggest either a much earlier bronze form or an iron axe. This principle can be illustrated by the find of a complete tool mark, on a piece of pine roundwood, from a site at Mablethorpe, Lincolnshire. The tool mark demonstrated the use of a metal axe with a blade measuring 130 mm and a gently curving edge (Godwin & Clifford, 1938, 394). The date of the site was not absolutely determined when the axe mark was recorded but a Late Bronze / Early Iron Age date was suggested. The width of the axe would seem to indicate the use of an iron tool (but see section 15.7).

None of the Oakbank axes exceed the maximum width of the Late Bronze Age forms. However, core group N represents an axe with a width of 79 mm. This is very close to the upper limit for Late Bronze Age socketed axes.

If the figures for the bronze socketed axe width distributions are examined it is apparent that, out of a data set of 673, there are only 61 examples that have a blade width of 60mm or above. All axes above 72 mm are of the Sompting type and out of 23 axes of 65 mm and above 16 are also of the Sompting type or one of its variants (Fig. 15.6). These heavy, broad bladed types have been considered as typologically very late often associated with material of the Llynfawr period (Schmidt & Burgess, 1981, 244; Coles, 1962, 36). Association with iron material is well known from this period. The Llynfawr hoard, for example, contained a socketed iron spear head, socketed iron sickle and a fragment of a Hallstatt C iron sword, in

addition to a number of bronze items, including a Sompting type axe (Crawford & Wheeler,1921). Distribution of these axe types within Northern Britain concentrates on the North and East Ridings of Yorkshire (Schmidt & Burgess,1981,247).

In Scotland there are only a few scattered examples of Sompting type axes. The closest example to Oakbank Crannog is that found at Cronan, Strathmore District, Perthshire. This find is an undecorated Sompting type with a cutting edge of 72 mm (op. cit. 242, axe no. 1588). Two other examples lie close to easily navigable waterway routes to Loch Tay one at Craichie, Dunnichen, Angus (op. cit. no. 1585) and the other at Gauldry, Fife (op. cit. no. 1641). It is interesting, however, that the largest examples of Sompting axes, or their variants, found anywhere in Northern Britain and Scotland are represented by beautifully preserved stone moulds both found in a hoard from Rosskeen, Ross and Cromarty. Furthermore, these discoveries combined with the rare find of a mould fragment in clay from Little Dunagoil, Bute (op. cit. no. 1642; Coles,1962,37) demonstrates that, although these broad bladed axe types concentrate in areas much further south, they were also being produced in Scotland.

To find axes, other than Sompting types, of similar dimensions to that of the axe N within the bronze axe catalogue much earlier forms have to be considered. The size of axe N clearly does not fit into any of the width distributions produced for finds of palstaves in Northern Britain and Scotland (fig.15.7 - 15.8). The largest known of the Later Short Flanged axes so far found is also smaller than this axe(Fig.15.3). Indeed the next type of axe that would accommodate a tool of the width of Group N is the Early Short Flanged type (Fig.15.9). These are placed by Schmidt and Burgess in the Acton Park Phase sometime before about 1300 BC.

The idea that the earliest construction of Oakbank Crannog was close 1300 BC is extremely unlikely. However, the fact that the top of pile 1744 (group N) was found more than 50cm below the loch bed silts, outside of the main boulder mound, might suggest the possibility of an earlier constructional phase. While this is the case signature links have now

associated this pile with parts of the structure known to be contemporary with much of the rest of the site and it consequently dates to around the middle of the first millennium BC.

15.4. The Oakbank axes and axe find blade edge curvatures.

Although it was clear from the dating of the site that earlier axe types did not produce the material observed at Oakbank, this possibility could be discounted on a comparison edge curvature alone. The edge shapes of all the Oakbank axes are clearly different from the majority of earlier tools. The average curvature index for the Oakbank material is 11.38% (standard deviation 2.79) while Early Short Flanged axes, for example, give an average of 28.42% (standard deviation 5.89). It is clear, therefore, that the earlier material has blade edges that are considerably more curved than those found at Oakbank; the same is true for all the earlier types.

Although it has been argued on the basis of width that if the production of pile 1744 was the product of a bronze tool it was most likely to have been produced by an axe of the Sompting type it is also clear that its width would fit within the distribution for socketed iron axes (fig.15.5, Table 15.1). To attempt to distinguish between the use of Late Bronze and Early Iron Age forms, the edge curvatures of these tools were considered in more detail and compared against those reconstructed from the Oakbank material

The corpus produced by Schmidt and Burgess (1981) again provided the basis for comparison. Of the 707 socketed axes within this volume some 520 were considered to have sufficiently undamaged blade edges. Examination of early iron axes was once again limited to the small number of finds recorded by Manning and Saunders and the recently discovered tool from Flag Fen. The average values for both iron and bronze axes as well as the Oakbank material are included in table 15.2. This table also gives a more detailed breakdown of the bronze data set according to the main types defined by Schmidt and Burgess.

It was difficult to draw definite conclusions from the measurements taken. It was, however, clear that on average Late Bronze Age socketed tools displayed a greater degree of edge curvature than those found at Oakbank or indeed the iron axes.

The bronze type that comes closest to the Oakbank curvature index average is Everthorpe. This type has only a general date bracket falling sometime in the Ewart Park phase (Schmidt and Burgess, 1981, 220). The distribution of the type concentrates in Yorkshire although one example was found at Castle Hill, Forfar, Angus. Although these axes have a similar curvature index to those found at Oakbank it should be noted that their edge width distribution is quite limited the largest blade represented being 50 mm in width. The Yorkshire type also has an average curvature close to that of the Oakbank axes. The number of axes defined within this group is substantial. These axes were produced over much of the Ewart Park phase and might consequently be argued to fit within the possible date range established for the site (op. cit., 238); however, again there is a fairly restricted width distribution with the largest axe being 58 mm in width.

On the basis of width the Sompting type axes are the closest form to axe N from Oakbank. However, examination of the edge curvature index of the Sompting type suggests that the form was generally more curved than any of those so far found at Oakbank. The average edge curvature for this type is 17.44% (standard deviation 7.68) which compares with the Oakbank value of 11.83%. It is interesting, however, that the Rosskeen moulds display axes with almost flat edges. The curvature observed on many of the Sompting axes is thus most likely to be the product of subsequent edge adaptation through hammering. The shape of the edge will therefore have been dictated to some degree by the user and may consequently be more variable. Furthermore, it could be argued that as the tool was used the blade would become progressively more curved as it was repeatedly hammered.

The Oakbank axes can be argued to mirror the average edge shape of the socketed iron axes far more closely than those established for the bronze material. The average edge

curvature index for iron axes is 12.54%, which is close to the Oakbank value of 11.38%. The limited nature of the iron data set makes such parallels difficult to demonstrate conclusively. Of the 21 Early Iron Age axes that have so far been found only 8 are sufficiently uncorroded to allow for assessment of the edge shape. However, while the data set is small it is drawn from a wide geographical area; 4 are from southern England, 1 from Wales, 2 from Scotland and 1 from Ireland. Consequently, it could be argued that the limited range of edge curvatures has additional significance.

15.5. Other facet features as indicators of tool form.

15.5.1. Facet length

The angle formed in the sharpening of a blade may be reflected in the length of facets found on a piece. A narrower angle might be expected to create less resistance during the execution of a blow and therefore result in longer facets.

This feature may suggest a shift from one material type to another. Marks left by stone compared to those left by metal is an obvious example. Facets produced by stone axes generally appear shorter and more dished in cross section (see below). This is presumably a product of the less acute sharpening angle obtainable on the blade edge of a stone tool. Such facets are well illustrated in the Somerset Levels papers for the Sweet track (Coles & Orme, 1984, Fig. 11-12). This characteristic of stone axe marks has also clearly been noted by O'Sullivan, during his examination of prehistoric wooden trackways, in the raised bogs of Co. Longford, Ireland. During this project O'Sullivan compared facet length on timbers from sites of Neolithic through to Iron age date. It was clear from this study that Neolithic facets were very much shorter than those produced with metal blades.

Although it was clear from the above study that stone and metal could be distinguished from each other given a sufficient sample size, distinguishing between different types of metal blade on this basis appears less certain. O'Sullivan's work indicates that Iron Age tool marks

are often longer than those found in preceding periods (1991,95). The facets from the Corlea 1 trackway (148 BC), for example, ranged in size from 2 - 10 cm and were clearly, on average, longer than those recorded from the Derryoghil 1 (938 \pm 9 BC) trackway timbers that, with two exceptions, were all below 5 cm in length. Table 15.3 summarises O'Sullivan's results for facet length and width from different trackways and compares them with those so far established for the Oakbank material.

It can be argued that the facets observed on the Corlea 1 and Derraghan 1 Iron Age trackways are the product of thin bladed shaft-hole axes of the Later Iron Age. The thinner blades can be argued to allow an axe to cut more closely to the direction of the grain of the wood and consequently longer facets are produced (O'Sullivan,1991,95). The lengths of the facets on the Oakbank material are close to but do not absolutely fit with this pattern. They appear to be generally shorter than those established for Iron Age material by O'Sullivan but somewhat longer than those characterised as Middle to Late Bronze Age in his work. These differences do not preclude the use of iron tools on the Oakbank material but it suggests that this attribute alone should be treated with caution. It is possible, for example, that iron socketed axes would produce somewhat shorter facets than later shaft-hole forms because of the manner in which they are hafted. As the form of these axes was similar to Late Bronze Age tools it could be argued that the dynamics of their use would also be similar.

15.5.2. Facet Cross section.

Facet cross section has also been raised as a distinguishing factor between bronze and iron tools. In commenting on structures south of Mere island in the Somerset Levels Coles noted that:

'there is a greater contrast between the flat facets left by iron tools and the concave ones of a bronze blade ... than between facets made with a bronze and a stone blade' (Coles & Orme,1978b,97).

This distinction has become entrenched in some subsequent literature. In examining some timber structures at King's Sedgemoor, for example, the comment was made that:

'all the worked pieces examined bore slightly concave facets, suggesting that they were probably shaped with tools made of stone or bronze rather than iron' (Norman & Clements,1979,14).

However, this feature may not be reliable. O'Sullivan's work on Irish trackways includes comments on material from three Middle to Later Bronze Age sites; from the working on these timbers he concludes that:

'it has been impossible to assess what actual types of tools were being used ... The facets are typically flat, and are of a medium size, generally not as wide as Early Bronze Age wood, but not as long as those produced by iron tools.'(1991,94).

Most of the piles raised from Oakbank Crannog display slightly dished facet surfaces although some flat facets can also be found. Such a mixture of flat and dished facets was noted for some Bronze Age sites on the Somerset Levels (Coles and Orme,1985,27). This also accords well with the experimental work conducted during this project. It was clear a bronze form regularly, although not always, produced dished facets while a modern steel axe consistently produced absolutely flat facets.

The foregoing would appear to indicate that bronze axes were in use on the site. However, this distinction should not be taken at face value. The argument for caution is similar to that given for the application of facet length. In other words it is not yet possible to fully define the dynamic differences between Late Bronze and Early Iron Age tools. Two factors can be argued to cause the dishing of facets: the nature of the blade and the manner of hafting both of which may effect the angle of cut. Coles has noted that blade angle (the angle made by the two opposing faces of the axe) and edge angle (the angle made at the extreme cutting edge through grinding and sharpening) will both vary the ultimate shape of a facet (Coles & Orme,1985,27).

Even a casual glance through the Schmidt and Burgess volume (1981) will immediately demonstrate the bulky nature of the blade angle of Late Bronze Age axes when compared with later iron axes. This bulk physically prevents the blade passing through the wood at very shallow angles and therefore the edge curvature is more readily registered down the facet. The

edge bulk observed in the majority of Late Bronze Age axes does not entirely disappear with the arrival of iron forms. The problem of the Early Iron Age data set has already been raised but the socketed forms found suggest that at least some iron axes had quite bulky blade angles (Manning & Saunders, 1972; Coombs, 1992, fig. 7.4).

Experimental work during the current study using a replica Late Bronze Age axe suggested that the dishing of the facets produced may in some part be a function of the hafting method. The hafting method for a Late Bronze Age Socketed axe places all the weight of the axe to one side of the haft. This tends to make the axe twist in the hand as it bites into the wood and may result in a deeper cut than is desirable. A shaft-hole axe has the weight of the tool more evenly distributed across the long axis of the handle. This allows for greater accuracy in the swing and therefore shallower cutting angles. The more acute the cut the less the curvature of the blade is reflected in the facet produced. Socketed axes with longer or heavier bodies amplify the twisting motion experienced when using the tool. This fact may have been the reason for a number of Bronze Age axe hafts being found with bulbous heads, this being an attempt both to add to and balance the weight of the axe. As Early Iron Age axes, even the ones that are not fully socketed, appear to have been hafted in a similar manner to later bronze forms it is felt that this feature of facet form may not entirely disappear with the arrival of iron.

To examine the hafting factor at a slightly more practical level some further experimental work was conducted. A thin bladed iron axe was used hafted with a centre of balance clearly to one side of the shaft. By using a blade with a thin body and acute edge angle it was hoped that the hafting factor could be isolated to some degree. The use of this axe clearly demonstrated the twisting motion noted for the bronze axe and, being thinner, the axe tended to bite into the wood to a greater degree leaving more jam features than noted for the bronze axe. The resultant facets were all slightly dished (Plates 15.1 - 15.2).

A further important reason for facet dishing may be traced to the haft itself. With a shaft-hole axe the wood of the haft nowhere protrudes beyond the head surface. Thus the blade can

pass as close to the wood surface as the taper of the tool head allows. With non-shaft-hole axes the wood of the haft can protrude beyond the head surface. In these cases the minimum angle of axe strike is dictated by the bulk of the haft head. A blade cutting into the wood surface at a shallow angle will produce a flat facet; as this angle increases the facet cross section begins to reflect the curvature of the blade edge.

It is difficult to isolate the factors leading to specific facet form; strength, expertise, tiredness, tool form, weight and hafting method will all contribute to the final shape. The experimentation clearly suggests that facet dishing is not a simple question of the difference between iron forms, with thin blades, against bronze forms, with fatter blades. It would certainly be difficult to assert that the dished nature of certain facets is a quality intrinsic to the nature of bronze; in other words tool form is crucial. That early iron forms may more closely resemble late bronze forms should logically lead to woodwork with similar facet shapes. However, once flat, longer facets (up to 9 cm or more), are found to predominate on timbers from a site, better balanced iron tools, perhaps with thinner sharpening angles, are clearly indicated (e.g. Brunning, 1991). Experimentation, with replica socketed iron axes, is required to examine the issue of transitional forms.

15.6. The Oakbank axes - summary and conclusion.

The preceding sections have shown the possibilities and limitations of comparing axe marks with known tool finds. Given the evidence available the tool used to produce pile 1744 and pile 1060 is either a bronze axe of the Sompting type or an iron socketed axe (including semi-socketed forms).

The following draws together the evidence for the most likely tool form used in the production of the Oakbank material, in particular the possibility that iron tools were used in the construction of the site is examined.

- **Early iron use** - The evidence for extensive use of iron for edge tools, before the closing centuries of the first millennium BC, is limited. The discovery of an iron socketed axe in apparent association with three bronze forms and a Hallstatt C bronze razor at Traprain Law might suggest the use of iron tools as far back as the seventh century BC at least in some parts of Scotland. However, as Turnbull has pointed out these finds come from levels with that have been assigned the same number but which are in different areas and their association cannot, therefore, be relied upon (Turnbull,1984,263). Similarly the date of the iron socketed axe from Bishop's Loch, Old Monkland, Lanarkshire, is impossible to determine.

- **Biases in the tool find data sets** - While there is very poor evidence for early iron use in Scotland it has already been noted in this chapter that iron is less likely to be found than Bronze. It has also been persuasively argued that the manner in which iron was recycled mitigated against regular deposition (Turnbull,1984,281). Thus it can be suggested that the observed hiatus:

'may be illusory, caused by the quality of the evidence and the current state of our understanding of the later prehistory of this area' (op.cit.,265).

Indeed it may only be through the discovery of larger axe marks on well dated timber sites that the shift to iron edge tools may be detected (see section 15.7).

- **Iron finds at Oakbank Crannog** - The find of an iron knife/arrow head would at first sight seem to prove the use of iron on the site. However, this was not found in-situ although it appears to have eroded out of the organic material in area A2. Some metal working debris has also been found on the site. It has been argued that the:

'growth of an iron silicate and iron/titanium oxides indicated iron working' (Dixon,1984b,270).

This material was found within the confines of the semi-circular pile feature, however:

'since the slag was found at the upper and lower layers it cannot be associated with one particular phase of occupation but its position in the organic matrix shows that it was being worked in the pre-boulder period' (op.cit.).

If this is indeed iron working debris it suggests that the crannog dwellers were not only familiar with iron they were actively involved in its production.

- **Reconstructed blade width distribution** - Both Group S and Group O have almost exactly the same width. Because of the small number of blades so far reconstructed it is not possible to determine whether this grouping of similar widths is going to be a common occurrence. The recurrence of similar widths across a site could be indicative of standard tool moulds and therefore a bronze tool kit. Unfortunately, axe S and O are not firmly related to the same phase; indeed it seems likely, from their stratigraphical relationship that O is in use some time after S and may, therefore simply be a different manifestation of the same axe.
- **Facet cross sections** - A number of the facets on most of the timbers are clearly dished which has been suggested as indicative of bronze forms. However, this has yet to be adequately proved as an exclusive trait for bronze tools. This feature of the facet may instead indicate the edge form and/or the hafting method. Consequently, this feature might suggest a socketed or semi-socketed axe rather than a particular metal type.
- **Blade widths** - Pile 1744 demonstrates the use of an axe of a width that is within the widest 3% of the 673 Late Bronze Age axe finds in Northern Britain and Scotland. This blade width also fits with the known early iron forms.
- **Blade curvatures** - The average edge curvature of the Oakbank tools fits most comfortably with the values produced for iron socketed axes.

In conclusion it seems reasonable to suggest that some of the tools being used at Oakbank were probably made of iron and most likely of the socketed or semi-socketed variety. This conclusion may be echoed in the find of an iron socketed axe close to or on a crannog in Bishop's Loch, Old Monkland, Lanarkshire (Manning & Saunders, 1972, 19). While an iron socketed axe has been suggested as the most likely contender for the working of the Oakbank

material this does not preclude the possibility that both bronze and iron forms may have been used for some of the structure.

More conclusive proof of the tool types used at Oakbank Crannog may be established as more wetland and submerged sites are investigated. As this occurs a database of tool marks will emerge, some of these may be directly related to tool finds while others will be more exactly dated. The following section explores the way in which such a database could be used.

15.7. Tool mark assemblages as a test of tool find data sets.

The conclusions drawn in the preceding sections rely on an assumption that the tool find data sets are a representative sample of the tools actually used. Furthermore, the chronological implications of some of the conclusions rely on the veracity of the underlying typological framework.

The extent to which tool finds are representative of the tool kit used during everyday operations may be called into question. In the case of bronze tools very few tool finds are made within a settlement setting. Indeed it has been pointed out that:

'the majority of Bronze Age axes in Scotland and northern England, i.e. about 90%, are in no way associated with other material.' (Schmidt & Burgess, 1981, 14)

This is a conclusion drawn from a data set of over 1700 finds.

In particular, it could be argued, that the larger elements of a tool kit are under represented in the archaeological record, particularly in the later phases of the Bronze Age. If it is imagined that the stray finds are chance losses, perhaps while travelling around away from settlements, larger forms may not be expected to be present as small light weight axes would be more readily carried for general wood cutting purposes. Larger forms may be reserved for work closer to the settlement, such as building and repair, and thus may be more likely to be recycled than lost.

Hoardings may represent a more complete sample of the tools that were actually used. However, the interpretation of hoardings still generates much debate and firm assertions about their contents in terms of everyday life are problematical (Schmidt & Burgess, 1981, 17-18; Bradley, 1988). It is clear, for example, that not all axe types found are represented in hoardings and a number of hoardings contain only axes of one type (Schmidt & Burgess, 1981, 18).

The last few sections have tried to place wooden material from the Oakbank site in the context of tool finds. However, on some sites it may be more profitable to turn the question around and use a known tool mark assemblage to assess the extent to which tool find assemblages are a true reflection of actual tool use.

The tool marks from Oakbank Crannog have already begun to indicate some important aspects about the later prehistoric tool kits in this area. In particular it was suggested above that the larger elements are missing from the tool find data. It is clear from the Oakbank timbers that, irrespective of the bronze/iron debate, small tools were employed for even quite major constructional tasks. Both Axe S and Axe O have blade widths of 45 mm. Despite their diminutive size the average diameter of the timbers worked by the axe S is 150 mm while pile 1582 (group O) has a diameter of 175 mm. The average diameter of the piles at Oakbank is 140 mm while the maximum so far found is 340 mm.

Oakbank Crannog is problematical because it has not yet been precisely dated. However, blade definitions from well-dated material, particularly with dendrochronological techniques, will reveal an accurate data set reflecting the actual dimensions of tools used at specific times. Consequently, changes in tool size and shape over time may be accurately determined and clearly linked to actual use. The results of these examinations could not only be used to check the representative nature of known tool finds they may also be used to draw conclusions about wooden material that is less easily dated.

CHAPTER 16

The use of tool mark results and dendrochronology.

Tool mark signatures and dendrochronology provide two complementary lines of evidence. There is a fundamental difference between the information each technique provides for a particular timber which makes their combined use of particular interest. Dendrochronology utilises naturally occurring growth cycles to establish absolute or relative dates for the felling, or at least cessation of growth, of a particular timber. Signature associations by contrast utilise anthropogenically induced signals to establish contemporary manufacture. Indeed, it can be argued that the connections uncovered by the latter represent far finer relative time slices than can ever be noted through dendrochronology (Coles, J.M. et al., 1988, 14).

The following chapter examines some of the ways in which tool signature information might be used in conjunction with other data from a site.

16.1. Dendrochronology at Oakbank Crannog.

A number of timbers from Oakbank Crannog have been analysed dendrochronologically. During the early 1980's some 258 samples were given to Dr. B.A. Crone as part of the data for her doctoral thesis. The material consisted of 126 roundwood uprights and 132 horizontal timbers.

As noted in previous chapters the predominant species used by the Oakbank inhabitants was alder. Alder readily responds to local climatic variations. In addition during its growth it may cease to lay down rings if subjected to climatic stress. Consequently, this species is not normally utilised for dendrochronological purposes and an examination of the problems and potential of alder provided the focus for Dr. Crone's work. As a result of the variability of alder growth it is not possible to use this species to create absolute chronologies and the work on the Oakbank material aimed at creating a relative chronology for the timbers examined.

None of the horizontal material that has been looked at from Oakbank bore signatures. Consequently, the 126 roundwood piles examined by Dr. Crone provided the core data for an investigation of the manner in which the two techniques might be used in conjunction. Of the 126 piles not all were still available for facet examination. The sixty piles that form the extension feature were the most heavily sampled in both the current study and Dr. Crone's study. Two thirds of the piles in this feature were examined for dendrochronology and nearly all had at least one facet cast.

16.2. Comparing signature results with dendrochronological information.

As a result of the difficulties associated with using alder it was clear from Dr. Crone's work that the production of unequivocal floating chronologies for the site was problematical. Two chronologies were produced. The first was based on standard dendrochronological procedures, the traditional approach. Dr. Crone saw problems with this procedure as it relied on a method of chronology building that was considered 'haphazard' when dealing with short ring sequences (Crone,1988,95). The building of a chronology utilising the traditional approach relied on the acceptance of pairs of sequences that matched well visually and which were substantiated by a sufficiently high statistical score (Schweingruber,1989). A chronology was thus built up 'pairwise' (curve A being matched to curve B, curve B to curve C and so on) and there was no way in which all of the relationships in the chronology could be examined for inconsistencies(op. cit.). It was not considered, for example, whether the position of a match for curve C on curve B was consistent with that derived for curve C on curve A.

To overcome the problems associated with the traditional methods, Dr. Crone developed a statistical procedure called the Sort.String approach. This attempted to circumvent the problem of inconsistencies between matches that had been noted for the traditional approach. Dr. Crone described the procedure as follows:

'If sequence A matches sequence B at Year X (where X can be derived from some previously established, absolute or relative, master, or from A or B themselves) then sequence C must match both A and B at a position which confirms the relationship between the latter two sequences. If a further sequence D is added to the group it must also match A, B and C in a position which does not bring it into conflict with any of the previously established relationships.' (Crone,1988,101)

Using this procedure groups of curves were suggested whose internal relationships should be assured.

The two chronology building techniques produced slightly different results (see section 16.4). and Dr. Crone concluded that:

'the only reliable correlations are those found between small groups of sequences, found mainly in blocks 1-22' (op. cit., 141).

The **blocks** mentioned by Dr. Crone were the basic groupings formed as a result of visual matches between individual tree ring curves and were the basis of the traditional approach to chronology building. The 22 blocks produced by Dr. Crone included 83 alder timbers from the original sample of 258. Each block consisted of a span of years defined by the earliest (arbitrary year 0) and latest plotted years of the curves in that group. Three of the blocks, 17, 18 and 19, related directly to matches between piles from the extension feature and these blocks are reproduced as figures 16.1 - 16.2.

Table 16.1 summarises the relationship between the dendrochronological information produced by Dr. Crone and the core groups established by signature links. The table includes all of the timbers in the core groups that have been examined for dendrochronology. The table gives the ring count for each timber (column 4), the block number in which each timber is placed (column 5), the relative year at which the tree stopped growing in that block (column 6) and the position of that timber in the traditional floating chronology (column 7). The position of the timbers in the floating Sort.String chronology is given in column 8. Table 16.1 also gives an additional number for each of the timbers in the extension feature (Column 3). This number refers to the original numbering system used for the extension feature, originally

referred to as area X. The X numbers were used by Dr. Crone and are thus included to allow the current study to be tied in with her work.

16.3. Signatures as a verification of dendrochronological information.

16.3.1. Identifying misplaced curves.

It is clear that a good signature link provides excellent evidence of associated manufacture. Matches between the tree rings on alder are rarely so clear and might be subject to debate. By examining signature associations alongside dendrochronological information it might be argued that anomalies and misplaced curves can be identified. The identification of these occurrences should, however, be approached with caution. A signature that links two timbers with apparently different felling dates need not imply a misplaced curve. Asynchronous felling dates amongst matched signature groups can arise as a result of the manner in which a particular species grows. This is particularly apparent in alder as this species need not put on a growth ring if it is under stress. Thus different timbers may give the impression of being felled in different years where in actuality this is not the case.

Alder trees may cease to grow before they are felled. In table 16.1 some timbers within the same signature group appear to be associated with different felling years. Timbers 1042 and 1043 in group M, for example, occur in block 17. The tree ring curve of 1042 ends in year 35 of that block while that of 1043 finishes in year 36. The apparent discrepancy can clearly be traced to physiological factors in the growth of alder rather than a dendrochronological error. In response to this issue Dr. Crone comments that:

'at present there is no way of quantifying the problem except to say that the modern alder study indicates that, in any assemblage of alder, at least 15% of samples may have up to five missing outer rings.' (Crone,1988,160)

In consequence when examining dendrochronological diagrams based on alder individual curves that appear to be ending up to five years apart may in fact represent the same felling date.

Only one example so far shows the possibility of a misplaced curve in the basic blocks. Timber 1036 (X21) is placed in block 17 with a final position at arbitrary year 46. The rest of the timbers in this block concentrate within 1 year of arbitrary year 35, some eleven years before the year given for pile 1036.

Figure 16.3 shows the piles in the extension feature from this block with their arbitrary year numbers. It is clear from the position of pile 1036 that it is unlikely to have been an individual repair eleven years after the main construction. The site has so far given no evidence that piles are removed during repair phases. This would be a difficult, if not impossible, task especially after the weight of the structure had provided additional driving force on the pile. It is more likely that when structures were repaired new piles were driven down close to the old timbers which were then left to rot away to loch bed level. This approach is clearly seen on other sites. At the Neolithic site of Charavines, in lake Paladru, France, for example, it is apparent from dendrochronology that rebuilding took place without removing the previous uprights (Bocquet, 1987, 52, fig. 34). Pile 1036 at Oakbank Crannog is not close to or an obvious replacement of any other pile.

Pile 1036 has now been positively linked with groups T and M. Examining the latter group demonstrates that there are timbers in the same group that have final year ring which falls in arbitrary year 35 of block 17 (timbers 1042 & 1043). These timbers are clearly associated with the working of pile 1036, and the alternative hypothesis, that this pile is a later replacement, can be shown to be improbable.

While pile 1036 is part of the general building phase that produced the extension feature it could still be argued that stockpiling or reuse had occurred. However, both of these explanations are extremely unlikely. For stockpiling to be seriously envisaged a situation would have to be proposed in which the 12 other timbers in block 17 were kept for eleven years or more and then pointed along with a newly felled timber (1036). The nature of alder would in any case tend to preclude the long-term storage or reuse of the timber. Alder

operates most efficiently as piling when unseasoned. Furthermore, its undoubted abundance around the shores of Loch Tay would make the need to store the timbers for as much as eleven years unlikely.

Thus, it seems fair to conclude that the curve produced from 1036 should be brought back to fit with the rest of the group ending somewhere around arbitrary year 35 of block 17; the best fit seems to be year 36. Figure 16.4 shows the tree ring curve for pile 1036 in its proposed new position as predicted by the signature match.

The ability to define anomalies in this way clearly has a bearing on the confidence with which basic blocks might be used. The curve for pile 1036 could either be removed from the block or the altered position accepted. In either case this may have important consequences for the average curve pattern for that block. As the average of the curves for each block are ultimately used to form the relative chronology or master curve for the site the adjustments resulting from signature evidence may have crucial implications.

16.3.2. Adding unplaced curves and the combination of blocks.

Dendrochronologists are wary of using archaeological determinations to guide their work because of the circular logic this can engender. In many respects this is a wise precaution. The use of features or stratigraphical interpretation provided by the excavator to guide assessment may lead to a desired answer but not necessarily a correct one. Features may not all be of one phase, repair being difficult to identify, and may be fanciful within a confusion of timbers. While these comments are valid it is felt that the quality of core group signature associations will prove useful in the examination of unplaced tree ring curves. The dual examination of timbers within the extension feature highlights how the two techniques might be used in conjunction to begin to incorporate these curves into the broader picture.

In total 11 of the 41 timbers sampled for dendrochronology from the extension feature were not placed in any of the diagrams produced by Dr. Crone. Furthermore, only 22 of the 41 were placed in basic blocks. The initial analysis of the tree rings and the signatures have been

conducted entirely independently. This process has produced a series of grouped timbers and interpretations that have been arrived at in isolation. The unbiased basis of both techniques is thus assured. Both techniques have independently suggested that the majority of the structure was put up as one phase. There is no evidence for the stockpiling, or reuse of any of the timbers from either line of evidence. It is thus considered that the piles were pointed very close to the time of felling. Consequently, signature groups can be directly related to a particular felling cycle. With the exception of pile 1036, discussed above, the basic association of groups to dendrochronological blocks supports these assertions. In all cases where timbers have been grouped by signature and looked at dendrochronologically the time of felling has been consistent. It thus appears safe to associate unplaced curves within signature groups to those blocks to which the groups are already positively linked.

Clarification of the above points is provided by one of the best and most certain of core signature groups. Group A contains nine timbers which have all undoubtedly been pointed by the same axe. Within this group two timbers have been firmly placed dendrochronologically in basic blocks. Timber 1035 is within block 17 and timber X12A is in block 18. Group A contains four other timbers that have been looked at dendrochronologically but have not been placed in the basic blocks: timbers 1047, 1050, 1052 and 1054 (table 16.1). As the axe that produced group A also produced groups G, M, and X there is additional evidence that the unplaced curves should be positioned around year 35 of block 17. It would be of interest to examine the curves for these unplaced timbers against these blocks in the light of the signature associations. Unfortunately, the raw data for these curves is not, at present, available for study.

After the basic blocks have been established by the dendrochronologist the figures from each individual curve in that block are averaged together to produce a new curve that represents the features of that block. It is clear that this averaging process has the effect of highlighting those features of each curve that are in common and suppressing areas of discrepancy. The aim of the process is to bring out the features of the trees' growth which are

most clearly related to general climatic factors. These averaged curves can then be used to assess the relationship between each of the blocks and eventually a relative chronology may be constructed. It would be productive to average not only the curves that have been placed in the block but also those that link to that block by signature matches. It might be that the curve produced removes many of the individual differences that made each of the unplaced curves difficult to fit.

In the same manner in which unplaced curves may be associated with established blocks so too can different blocks be linked. Members of group A occur in both block 17 and 18 and these blocks might be confidently linked. Blocks 17 and 18 have not been linked on dendrochronological grounds. The links between these groups through signature associations is very firm and investigation into the reasons why the tree ring curves do not match should prove fruitful.

16.3.3. An economy of information ?

The previous paragraphs have examined the positioning of unplaced curves in known blocks through signature matches. This principal might be extended to unmeasured or unmeasurable timbers. The process would produce an economy of information whereby the data known about one set of timbers might be transferred to another set by virtue of their signature match. This could include both dendrochronology and radiocarbon information.

If a good chronology was available for the site certain **signature suites** might be associated with particular stages of that chronology. Subsequent finds of any member of that suite could identify the phase of construction at the time of excavation. At a site like Oakbank, where all of the alder uprights of one structural phase are likely to have been felled, pointed and driven within a short period of time, such associations can give valuable and rapid information about relationships on the site. Such information, because it is possible to establish links on the day that a signature is recorded, can aid the excavators while an excavation season is in progress.

16.4. Site phasing, signature links and the site chronologies.

The problems associated with alder prevented the production of an absolute chronology for the Oakbank timbers. Two relative chronologies were produced for the site based on traditional dendrochronological methods and the Sort.String approach (see above). The two chronologies differed from each other in a number of respects and are shown in figures 16.5 and 16.6. The difference between the chronologies prompted Dr. Crone to pose the question:

'how do we judge which chronology is the "correct" one ?' (Crone,1988,140).

It is possible that good signature links will provide the essential evidence that corroborates one of the two chronologies.

Pile 1744 (group N) illustrates the manner in which unmeasured timbers may be associated with measured material. This timber also demonstrates how signature links can be used to clarify aspects of building phases and investigate the suggested chronologies for the site.

Pile 1744 is important for having been found in amongst a collection of timbers some 50 cm below the present level of the loch bed silts and outside the mound of boulders that superficially define the extent of the site. In combination with excavations in area E2 the discovery of these timbers made it clear that the main site was more extensive than the capping of boulders would suggest. The location and size of these piles suggested the possibility that an early part of the crannog structure was being observed. This structure can most probably be equated with the first phase of construction outlined by Dixon; that of the initial free standing building.

Group N clearly linked pile 1744 to pile 1060. As the top of pile 1060 was flush with the present level of the loch bed silts it was apparent that the depth of 1744 need imply little about its age relative to the rest of the site. Pile 1060 was included in the 60 piles that formed the extension feature. However, its position close to the main crannog mound made this specific

association uncertain. While 1060 may or may not have had a direct structural role in supporting the extension feature it was clear from dendrochronology that the timber was felled close to the time that other timbers that were clearly part of this structure were cut down (see Group N, table 16.1).

Pile 1744 was a major structural upright clearly forming part of the main building support. The signature link to 1060 indicated that it was part of the same constructional phase. Consequently, the dendrochronological association between the extension material and 1060 could also be applied to 1744; a good example of the economy of information discussed above. This implied that the extension feature was built at the same time as, or at least within a year, of major constructional work involving the placing of principal supporting timbers possibly for the outer walkway of the main site. This inference was assured because in both cases definite links were being used; core signature groups on the one hand and basic dendrochronological blocks on the other.

Examination of the traditional chronology in the light of the above suggests interesting relationships. The extension feature is placed around year 83 of the floating traditional chronology. Pile 1060 is placed in year 82 consequently 1744 may also be considered to have been felled in this year. This would seem reasonable until the rest of the chronology is considered. Of particular importance is the floor feature known as F24. This is described as the upper floor layer and is placed in the floating traditional chronology between years 61 and 64. In other words if the chronology is correct pile 1744 was not in place until approximately 18 years after the timbers for the upper floor layer were felled. This would indicate that far from being an early part of the structure 1744 was a comparatively late addition. Stockpiling might be suggested but as indicated above this is unlikely at Oakbank and certainly not over a period of eighteen years.

The extension feature and pile 1060 could reasonably be argued to be a later addition. However, this is less clear in the case of pile 1744. If the chronology is correct and 1744 is truly part of a much later constructional phase it seems to imply considerable rebuilding of

major parts of the structure. If this is the case it is curious that pile 1744 should have produced the earliest radiocarbon date from the site so far. Although the radiocarbon dates are problematical for this period there is a suggestion on statistical grounds that at the very least pile 1744 can be considered within a broad earlier constructional phase (see chapter 5).

In the Sort.String chronology the floor features F24 and F17 are more closely associated with the extension feature and pile 1060. In this chronology timber 585 (F24) is placed with the same end year as pile 1060 which indicates a similar end year for pile 1744 by virtue of the signature association in group N. Given the arguments outlined above this seems a more likely chronological relationship.

Although there is a good depth of material under F24 this need not imply that the timbers of that floor feature are a later phase of construction. If F24 is a floor feature, associated with major primary outer walkway supports, such as pile 1744, and consequently the primary free standing structure, it follows that subsequent occupation rubbish could accumulate below it before the floor itself ceased to be usable. Thus, when the floor collapsed and sank it would come to rest on a mound of material much of which was more recent in production. However, the excavation of this material suggests that the material underneath F17 and F24 is part of a further floor feature. Consequently, if the Sort.String chronology is accepted it suggests that 1744 may still not be part of the very earliest construction on the site.

Although the Sort.String chronology appears to give a more realistic image of the site construction it is clear that there are a few misplaced curves. Signature associations clearly highlight where this is the case. Pile 1050 (X28), for example, is placed at year 70. This pile is undoubtedly part of core group A and its signature clearly matches all other members of that group. 1050 also has facets that clearly link the timber to core group G a group which has subsequently been shown to be a manifestation of axe A. This pile is thus directly linked with at least 14 other timbers. Of these 14 there are 3 which are also represented in the Sort.String chronology. All 3 of these timbers (1035, 1056 and 1058) ceased to grow in year 47 some 23 years before that proposed for Pile 1050 (X28). It is fair to conclude that this pile

has been misplaced and should be brought back in line with the rest of its signature group. A similar revision can be proposed for pile 1007 (X5), placed at year 68. A signature association with pile 1010 (group I) would suggest a new position for this pile at around year 47.

16.5. Patterns of association

16.5.1. Signature groups and tree ring growth.

It was noted above that alder actively responds to the local microclimate. Dr. Crone has suggested that this response may be reflected in the closeness of fit observed within the basic visually matched blocks. A number of the blocks may represent groups from particular stands of trees. Each set of trees would be subjected to differing microclimates. Thus the individual members of each stand would match more closely the growth pattern of other members of the same group than they would with trees from elsewhere. Indeed Dr. Crone suggests that the success in the use of short ring sequences has, in the past, been largely the result of the fact that the trees involved were all felled in one location and were, therefore, subject to very similar growth conditions (1988,165-166).

As alder fringes much of Loch Tay it would not be surprising to find timber collected from various locations, perhaps even floated across the loch. Each of these timber sources might have had distinct growth conditions. Different timber sources have been noted by dendrochronologists on other sites. Morgan, for example, was able to suggest just such a scenario for the Meare Heath track in the Somerset Levels (1988,26-28).

The collection of timbers from different stands may be suggested for timbers within the extension feature. Blocks 17, 18 and 19 all contain timbers from this structure. Despite the fact that many of the timbers in each block are clearly part of a single phase construction it has not proved possible to associate the blocks on dendrochronological grounds (see above).

The comparison of signature groupings to blocks has begun to suggest that there is a pattern of signature associations that could reflect the working of timbers from different sources. If members of groups F, I and J are considered it can be seen that in all three cases the traditional link places them in block 18 representing 4 out of the 5 timbers within that block. None of the timbers in these groups have been placed in any other block. Two group B timbers and a group H timber are associated in block 19. By contrast block 17 contains mostly group A, C, G, M, T and X. This collection of groups is significant as they have now either been shown to be the same axe (A, G, M, T, X) or at least found on the same timber (M & C). If this is a true pattern and it continues to persist it may be considered to reflect the working of timbers to a point close to the place of felling. In this situation a direct relationship would be formed between the physiology of a particular stand of trees and the axes used to point those timbers.

There are some timbers which break the neat scenario outlined above. Of particular importance is timber X12A which is clearly in group A but which is equally clearly associated with block 18. There may, however, be other explanations for direct associations between physiological groupings and signature groupings. It can be argued, for example, that the timbers were piled up close to the site in collections that reflected the order in which they arrived. It may thus be possible that one worker drew predominantly from one collection of timbers cut down from a particular source while another drew from a second collection derived from another source. If this were the case it would suggest that a pattern of association could build up which might only be disrupted if, for example, a worker finished one heap of timbers and moved to a second.

The evidence of consistent association in this study is at present too limited to be used with confidence, suggesting a pattern rather than proving a point. However, if the patterns observed prove to be persistent with only occasional exceptions it would seem legitimate to propose that most of the pile preparation was being undertaken at the felling site. If an

underlying pattern remains but there are a significant number of exceptions it might suggest work closer to the site on groups of timbers forming discrete collections awaiting use.

16.5.2. Signature groups and stockpiling.

The stockpiling of timbers has been introduced above as a possible explanation for discrepancies between signature and dendrochronological associations. This section examines how the storage of timbers prior to construction might be reflected in the relationship between these two lines of evidence.

Storage of timbers from one year to the next in preparation for major building programmes has been well attested to at the Late Bronze age site of Cortaillod-Est (1010/995 BC). The house plans and related timbers were established by the director, Béat Arnold, on the basis of the geometrical alignments of the posts and the distribution of finds across the site (Gassmann, 1989, 106). By superimposing dendrochronological information on to this ground plan it was indicated that many of the eighteen houses that comprised the lake side settlement were constructed from trees that were felled in different years (*op. cit.*, fig.1). In at least two of the houses the timbers used were felled over a period of four years (*op. cit.*, 111).

When stockpiling has occurred it might be suggested that timbers bearing the same signatures can have asynchronous felling dates. The logic behind this suggestion is that the timbers were actually worked at the time of construction and, therefore, had no direct connection with the period of felling. If this pattern were identified on a regular basis there would be little doubt of the fact that stockpiling had occurred. If the same signature occurred only once or twice on asynchronous pieces it might be more suggestive of an error in the placing of those individual curves (see above).

On sites, such as Cortaillod-Est, where the structural patterns are clear, signature association in parallel with dendrochronological information could help elucidate whether or not pointing was done in the year of driving or in the year of felling. Consistent association of signature groups to felling years in a demonstrably single phase construction that contains trees felled in

different years may be considered good evidence that the pointing was conducted at the time of felling.

While the above seems reasonable there are possible situations in which this pattern may emerge but which do not imply pointing at the time of felling. If stockpiled trees from different years are kept in separate piles one group of workers may work on one collection of trees while another group points a different collection. In this case signature suites could be consistently associated with a year of felling but may actually represent pointing at the time of construction. However, even if this were the case some discrepancies would be expected. Given different rates of work, different amounts of timber and working over a number of days, it would not be unreasonable to assume that at some point the same axe was used on different stockpiles.

16.5.3. Signature groups and reuse

Reuse might also be identified using dendrochronological information in parallel with signature groupings. In a situation where the dendrochronology is assured but the structure confused it might be possible to tease out the shape of buildings through signature association and dendrochronology. However, the dendrochronology may show one timber to be substantially older than other timbers in the area but the signature links it to the rest of the structure. If the dendrochronological position is sound timber reuse may be concluded.

16.6. Conclusions

Any two techniques which can be considered to have an inter-relationship should be looked at in conjunction. The concurrence of independently produced data substantially increases the confidence with which that information can be used. Conversely, the deviations between information can highlight possibilities that may not have been considered if either one of the techniques had been looked at in isolation. The work so far conducted at Oakbank suggests

there are considerable advantages to conducting a dendrochronological programme in parallel with signature recording.

Despite the fact that the current study and the dendrochronological study were not devised in parallel it has been shown that additional information can be derived from the overlaps in the data examined. It has to be stated, however, that at Oakbank such parallel investigations may only be viable for non-oak species such as alder. Mature oak has yet to demonstrate a usable signature on the site. This is a great pity as it is the oak that is most useful dendrochronologically. On the other hand, for sites such as Oakbank Crannog, where oak is rare and alder plentiful it should prove invaluable. This is particularly true when the complications of using alder as a dendrochronological species are considered. It is thus perhaps fortuitous that where tree ring studies start to encounter difficulties signature survival is at its best.

CHAPTER 17

Computer Analysis.

Previous chapters have demonstrated the manner in which tool marks and their signatures may be used within the context of submerged settlements. To facilitate this examination, methods of data retrieval and analysis have been developed that have proved to work well. Having said this, however, there is room for further consideration of the methodological aspects of the project. In particular ways in which the comparison process might be enhanced can be considered and investigated.

Establishing groups using visual comparison might be considered too subjective to fully utilise the information that may be available amongst a large sample set. A method that could objectively quantify the similarities or differences between casts would clearly be desirable. The following chapter examines the possibilities for implementing computer aided recording and comparison.

17.1. Computers and the present study

Computer storage and data manipulation have become an everyday tool within archaeology. There can be no doubt that it can be a highly useful and indeed essential part of many operations at both excavation and post excavation level. In this project the use of computers to handle signature information can be considered on two levels:

- A convenient storage method that can, perhaps, be integrated with the rest of the site database; allowing for human comparison at a later stage.
- Automation of the bulk of the comparison process.

In either case the first problem to be overcome is that of converting the signature into digital form. This problem might be approached in two ways:

- Processes that result in a digital record of the actual form of the tool mark, i.e. the height and width of each ridge and groove are recorded and stored as an array of figures representing a series of real profiles across the facet.
- Processes that result in a digital representation of the mark. The most obvious example of this is a device that captures images; the image being a light contrast record of the object.

Once the signature is reduced to a series of figures the problem of storage, manipulation and comparison can then be approached.

17.2. Data capture - possibilities from the archaeological literature

Dendrochronological measurement is one of the first techniques that might be considered as applicable to the recording of signatures; with this method data capture is achieved using a uni-axis travelling table with a measuring attachment connected to a computer. A fixed microscope enables the operator to observe the ring pattern of the timber. The position of each ring can be recorded with the push of a button as it passes under the cross-hairs of the microscope's eyepieces (Schweingruber, 1989, 52-53).

Signatures can be measured on a one dimensional basis using dendrochronological equipment. This method has been used to good effect during this project to check on variability within known signature groups (see section 11.1). However, examination of the detail of a facet surface under a microscope demonstrates the difficulty of defining exactly where one measurement should stop and another begin. Tree ring measurements are neatly defined by boundaries generated by yearly growth cycles. Signature features are not produced by organic rhythms and extra ridges and missing features are common place. In other words a signature is not a clearly defined sequence of one dimensional measurements.

Ambiguity in the definition of a ridge is partly a semantic one. Tool mark signatures should be considered as a continuous and varying line rather than a series of ridges or grooves that can be measured in isolation. To examine the physical reality of such a line a method for recording height and width data from a facet was considered. During the short pilot study into the wooden material from Oakbank Crannog the 'Reflex Microscope' was used to try and

achieve this sort of recording (see chapter 8). The machine proved effective in producing profiles but it was felt that in the long term the process was too slow. An operator has to record a considerable number of points to adequately reproduce the physical reality of the mark, more than 150 points in some cases. Such intensive recording takes time, approximately 10 - 15 minutes on average per sample, and this can represent a considerable amount of time when dealing with a large data set.

It can also be noted that signatures are not necessarily consistent along their length. Points of damage, erosion effects, characteristics of tool use and orientation of grain all contribute to subtle and not so subtle variations across a single profile. Consequently, to adequately record a mark using the Reflex Microscope a number of profiles would be required and the results then averaged. It can be thus envisaged that the data capture time would have to increase quite dramatically if this technique was to be used to adequately store and manipulate signatures. Such an increase in time would be undesirable and the technique was rejected.

Part of the disadvantage of the above method of data capture was that an operator had to individually record the points across a profile. A more mechanical system would thus perhaps be desirable. Just such a system is described in an article on the measurement of tooth crown surfaces (Hillson and Jones, 1989). Two techniques were examined in this article. The first was a version of the technique described above, although built and developed by the authors at a more affordable price. The other technique examined was physical profiling. The machine used to conduct this process is described in detail by Hillson and Jones (*op. cit.*, 98). It consists of a sapphire gramophone stylus mounted at the end of the piston of a linear displacement transducer sitting vertically over a specimen stage. The specimen stage is movable in one direction and is attached to a transducer, which gives a measure of the horizontal movement as the stage is moved. The stylus moves up and down as the specimen is run underneath it giving the vertical measurement.

The advantage of the Hillson and Jones method over the Reflex Microscope would be the increased subjectivity and, possibly, a faster processing time. However, even using this

method a standard of around 6 minutes was suggested for each profile (op.cit.). Furthermore, considering that Hillson and Jones were measuring objects considerably smaller than a facet it was apparent that this technique might also be considered time consuming.

Although physical profiling had drawbacks some enquiries were made into the possibility of using a similar machine at the mechanical engineering department of the University of Edinburgh. However, the machine looked at did not provide the level of resolution required for the task in hand. Its use was largely to determine general features of surface roughness rather than specific detail as in the case of Hillson and Jones technique. In the end it was decided to reject this possibility. The recording time, the need to take more than one profile and the fact that such machinery was not generally accessible at a reasonable price all suggested that other techniques should be considered before this particular approach was adopted at a practical level.

Investigations into microwear on stone tool surfaces have produced a number of methodologies over the past few years. Many of these have had the aim of removing the subjective descriptions of polish such as 'greasy' (Keeley,1980,43) thereby allowing for the production of comparable results. Of particular interest to the current project was an optical method that used the **grey-scale** values of **pixels** in a digitised image (Grace,1989,18); in this study photographs were taken through a microscope and the image converted to a digital form using a rotary drum scanner. This machine digitised the image into a series of pixels each with their own grey-scale value. The digitised tonal variation of the image could then be assessed and subjected to statistical analysis (Grace,1989,18-48). Of all the techniques so far encountered it was felt that this provided the best chance of overall success and was thus considered in greater detail.

17.3. Image analysis - an outline approach

A series of discussions with Edinburgh University's Department of Artificial intelligence suggested that digitised images could in principle be used as the basic data for a signature

comparison system. During the initial discussion phase four casts from Oakbank Crannog were given to Andrew Fitzgibbon, a researcher in the department, who was able to suggest the outline of a method through which the marks could be reduced to a digital form and matched together.

The image analysis approach can be split into a series of stages:

- **Data acquisition** - By capturing an image of a cast using video or scanning equipment the picture is reduced to a series of values that represent the light intensity at each point of an image (the grey-scale value). The cast needs to be oriented so that the ridges are running from the top to the bottom of the image. It also needs to be side lit to enhance the ridges and grooves of the signature.
- **Image selection** - An area of the captured image needs to be selected that contains only the signature elements, i.e. the ridges or grooves of a single facet. This selection ensures that only true signature elements are considered by the computer during the matching process.
- **Image smoothing** - Image capture and selection ensures that the ridges and grooves of a signature are oriented from the top to the bottom of an image. As these features are the focus of interest they can be enhanced by averaging the values in each column of pixels. In this manner any feature that is not vertical in the image is suppressed, this might include areas of damage or grain features. The consequence of the smoothing process is that each cast can be represented by a single string of numbers that represents a light profile across a signature and this can be expressed as a graph (see figs.17.1-17.2). This method contrasts with physical profiling techniques that require a number of profiles to adequately define the mark. With image capture techniques the whole facet is included in one frame.
- **Light Profile adjustment** - The position and intensity of the light source create variations between images that are independent of the light variation generated by the signature pattern. Consequently some form of filtering and normalisation of the profiles is required before the

curves can be compared for matching. The principal variation seen in the profiles is the fall off of light across the image, which results from the side lighting required to enhance the signatures.

- **Light Profile matching** - A curve matching technique is required to establish the best position of fit between two light profiles.

17.4. Image analysis - a practical implementation

As part of this project a computer program (SigMatch) has been developed by the author to operate within the Windows environment on an IBM type machine. The development of this program enabled the approach outlined in the last section to be examined in detail. While the outline approach suggested the framework for the image analysis, at each stage there were different ways in which it could be implemented. The different aspects of this examination are discussed in the following sections.

17.4.1. Data Capture

Images for the prototype system were initially captured using a 'Logitec Scanman' passed over black and white photographs. The 'Logitec Scanman' is a hand-held 256 grey-scale scanning device. It can record any flat image at a resolution of up to 400 dots-per-inch (**dpi**) and each of the dots can have a value between 0 and 255. A zero value represents black while a value of 255 represents white. Values between 0 and 255 represent shades of grey from black to white (see also Ballard & Brown,1983). The device is run by software (Ansel 1.0) on an IBM type machine. The software can store the image scanned by the device in a number of file formats including bitmap files (BMP) the file format read by the SigMatch program (see section 17.4.2).

The use of the Scanman device proved adequate and was necessary as it was the only equipment available at the time with the necessary specifications. The data acquisition stage

required the equipment to register a range 256 grey shades at a resolution of around 200 dots per inch (dpi) when the cast image being digitised was at a scale of 1:1; this was well within the capabilities of the scanning device used.

Although the scanning approach was adequate it did introduce an additional photographic stage. The system would be most efficient if some form of video capture was utilised. This would enable images to be taken directly from the casts or possibly even directly from timber surfaces. Again the only requirements are that the equipment pick up sufficient tonal variation and that the image has sufficient resolution.

The choice of input package is fairly extensive but once a system is chosen it is important that the set up is maintained throughout the project to ensure that each image is truly comparable. Two factors are especially important at the data capture stage to ensure good results. Firstly, a consistent camera to object distance must be maintained, if this distance varies it alters the scale of each image and signature features will not match up. Secondly, the lighting of the casts should be as consistent as possible. This includes factors such as lamp angle, the distance of the lamp from the object, and the strength of the bulb. Again there are no absolute rules for this set up other than placing the bulb in such a manner that the signature features have sufficient highlights. Similarly the bulb angle should not be so low that the image is swamped by shadow. Whatever the final choice of set up it should be recorded and maintained throughout the project to ensure comparable results.

In the future, it is possible that routines could be written into the software that took slightly differing scales and lighting variation in to account. At present, however, it is easier to ensure standard conditions at the data capture stage than it is to implement these routines.

17.4.2. Image storage

The Ansel software that controlled the hand-scanner stored the scanned image as a bitmap file (BMP). The software also enabled the user to select which areas of the image to store in the file; as mentioned above an area of the image needed to be selected so that only the

signature elements were recorded and stored. In addition the image had to be oriented such that the ridges of each signature were vertical in the image. This could be achieved at the time of capture but the Ansel software also allowed for the image to be reoriented on screen.

The BMP file format is the basic image type for the Windows environment. Each BMP file consists of a header section and a data section. The header defines the nature of the image, storing information such as the size and colour range of the picture. The data section can be thought of as an array of numbers that define the grey shade value of each pixel in the image. The first number in the data section is the value of the top left most pixel in the image while the last value is the bottom right hand pixel (fig.17.1). Each pixel is stored as a single byte in the data section and consequently can have any value between 0 and 255 representing the grey-scale values described above (see also glossary).

The first stage of analysis involves averaging each consecutive column of values across an image. For example, each value in column one is added together and the divided by the height of the image in pixels this is then repeated for every other column across an image.

At this stage the entire signature is reduced to a string of numbers with as many values as there are pixels in the width of the image (Fig.17.1). This represents a very economical way of storing signature information. This information can be represented as either a graph or may be re-expanded into a BMP file format so that a smoothed image of the signature can be viewed (Fig.17.2). Such possibilities represent a considerable saving on disk space when compared with the storage space required for raw image files.

17.4.3. Light Profile Adjustment

The light profile reflects not only the signature pattern but also the position and intensity of the light source. In particular the grey-scale values demonstrate a trend that denotes the reduction in light across an image with increasing distance from the source. This factor has to be accounted for before light profiles from different facets can be directly compared.

The need to correct for a trend in the light profile is similar to the dendrochronologists' problem of having to adjust for long-term variations caused by factors such as ring width changes resulting from a tree's age; rings put on early in a tree's life are wider than those put on later. The dendrochronologist traditionally overcomes this problem by utilising 5 year running means to detect the underlying trend (Schweingruber,1989,84). The raw values are then subtracted from the trend line to produced a series of figures that reflect ring width variation resulting purely from environmental changes. This approach highlights a principal difference between the dendrochronological curve and a light profile. In a dendrochronological graph each peak or trough in the curve normally reflects a single ring width, in a light profile these features are made up of a series of pixel values; consequently, using running means on a light profile tends to flatten the profile to an unacceptable extent.

The SigMatch Program at present uses a simple regression analysis to adjust for light variation across a profile (Fig.17.2). This appears to work well, however, it should be noted that more dishd facets complicate the manner in which the casts reflect light. There may in this case be less reflected light on the surface closest to the light source and most on the far curved surface. Consequently, it may be necessary in future versions of the program to establish a better method of detecting underlying trends in the light profiles; a possibility might be a form of running regression analysis.

In the SigMatch program the raw values at each pixel position are subtracted from the regression line values (Fig.17.2). This process is referred to as indexing and produces a series of figures that should only represent the light pattern that is a direct result of the ridges and grooves in the signature. However, examination of the graphs suggests that there is a low frequency pattern within the light profiles that cannot be entirely accounted for by the signature pattern. This pattern may be explained by a general surface texture that is common to cut wood surfaces; this texture can best be regarded as a product of the cellular structure of the wood. At present this underlying fluctuation does not appear to have a significant influence on the matching process. However, it might be worth attempting to remove this low

frequency signal to ensure that matches are only influenced by clear signature details. The manner in which this might be achieved has not yet been determined.

17.4.4. Signature matching

Once the light profiles have been indexed a technique is required that will establish a measure of similarity between two curves. As the computer program was a late development in this project it was decided to try techniques established for the matching of dendrochronological curves.

Many curve matching techniques are based on a statistic known as the correlation coefficient. This is defined as the ratio of the product of the standard deviations of X and Y to the covariance of X and Y , where, in this case, X and Y represent the respective numbers, in each of the light curves, at a particular position of overlap (Walsh,1990,246). It gives a measure of the extent to which two sets of values respond in the same way around their respective means. This measurement results in a value between -1 and +1 for a particular position of overlap. A value of +1 indicates that the two sets of values are identical, a -1 value indicates that the values are negatively identical, that is when a value in one curve is high it is low in the other, a zero indicates no relationship between the values (fig17.3).

The SigMatch program passes one set of figures past the other. At each position of overlap the correlation coefficient (the r -value) is calculated. In the initial versions of the program the matching process utilised only this test. Once each r -value had been calculated for each position of overlap the best match was chosen by searching for the position with the highest value of r . This worked well for most of the images in the test group (Fig.17.4). However, occasionally a position was suggested by the program when a better visual match was available.

Mismatches using the r -value result from the fact that the statistic does not take into account the amount of overlap between two sets of figures. A small overlap may produce a high r -value because there are only a few figures involved in the calculation.

Dendrochronologists have overcome this problem by utilising a test that incorporates the overlap figure into the calculation. The most commonly used test in dendrochronology is the t -test. This test uses both the r -value and incorporates the overlap, which provides the basis for a measure of the degrees of freedom; the overlap value minus two. Use of this test appears, at this stage, to be effective. Although the sample set is still small no mismatch has been found between two casts of the same group (Fig.17.4).

When two images are compared by the program a position of fit will always be suggested whether or not a true match is apparent to the eye. The SigMatch program looks for the highest t -value for every position of fit and displays the images together at that position. When two casts are from different groups the highest t -value will be relatively low (Fig.17.5). To identify true matches a threshold t -value below which a match is not considered to be sufficiently similar to suggest inclusion into a group must be identified. In dendrochronology the traditional threshold value is taken to be when t equals 3.5. For light profiles it was soon apparent that the value of 3.5 was far too low; at present it appears that any value below 6.5 is unlikely to be reliable for light curves. The higher t -value for light curves appears to be the result of the fact that each peak or trough is made up of a series of pixel values.

The program allows the user to choose from three different tests to allow for a comparison between approaches (fig.17.6). These three tests are the plain r -value, the t -test and the z -score. The z -score has been included as this is the statistic that critics of the use of the t -test in dendrochronology have advocated as an alternative. The t -test has been criticised as it still gives a bias toward short overlaps. The z -score is considered to counteract this problem. Further experimentation is required to establish the best statistical test.

17.4.5. Variation in inter-ridge distance and signature matching

So far the discussion of automated matching has left out one potentially important consideration, that of inter-ridge distance variations. The variation between signatures from the same tool, caused by an axe blade not travelling through the wood at right angles to the

direction of force, potentially results in the contraction of the distance between the ridges of a signature (see chapter 2 and 11). This contraction can lead to difficulties in correlation as light profiles appear slightly out of phase with each other .

Some of the images in the sample set show this factor but so far the SigMatch program has successfully placed the images together at the same position as visual inspection. The position given seems to be based on the boldest area in the image; a logical result as these areas will have a greater number of pixels responding in the same way. However, the *t*-value is much lower than those established between images that do not display this variation (Fig.17.7).

Two solutions to this problem might be suggested. Firstly, given that the distance between ridges can never be greater than that original displayed on the blade edge, images should be selected that display broader, straighter areas of signature registration. Experience has shown that these areas tend to fit far more exactly than areas close to or on points at which the signature is clearly starting to curve. A second approach would be to mathematically stretch or compress one light profile against the other to see if a better fit is available. As the ridges are the result of fixed areas of damage along an edge the discrepancies discussed above ought to vary as a ratio.

The possibility of the mathematical approach, described in the last paragraph, has not yet been examined in detail. However, at a theoretical level it may be commented that if the data is stretched or squeezed too much misfits may be generated. At present it appears that slight discrepancies between signatures are not as problematical as they might have at first appeared. It is apparent from the groups established by visual comparison that many matches are very close.

The variation in inter-ridge distance may conform to a continuum from an extreme compression to the original distances represented on the blade edge. As a consequence, it is suggested that theoretically it may be found that cast A fits well with cast B, cast B with cast C but cast C has a fairly low value for its match with cast A. In this situation it may be

indicated that the low value of the latter is the result of differing inter-ridge distance, because both A and C correlate acceptably with B. This form of inference is discussed more fully below (section 17.5.3)

17.4.6. Preliminary results

Table 17.1 shows some preliminary results from the SigMatch program. The table is constructed as a correlation matrix with the numbers of the casts examined running along the top and down the side of the table. The intersection between each row and column indicates the highest *t*-value established between each pair of casts; for example, if the cast of the facet from pile 1017 is examined against that from pile 1012 a *t*-value of 10.26 results. This is a very high value and indicates that there is a very high probability that these two images match; if by contrast the facet from pile 1056 is examined against that from 1025 a *t*-value of 2.90 results indicating that there is only limited similarity between these two images.

Along the bottom and up the right hand sides of table 17.1 have been placed the letter of the core group to which each cast facet belongs. It can be seen that, in most cases, values between members of the same group are higher than between members of different groups. In situations where this is not the case it is either lighting direction or variation in inter-ridge distance that has caused the problem (see sections 17.4.5 & 17.5.1).

17.5. Further developments

17.5.1. Accounting for signature orientation

The SigMatch program is at an experimental and demonstration stage only. There are a number of aspects that need to be considered before the program can be developed into a practical comparison tool. One such aspect is the need to take into account the orientation of the signature.

When examining the groups established earlier in this project it is clear that not all members in a given group were originally oriented in the same direction on the pile from which they were cast. The use of the tool in different directions or the use of a forehand or backhand strike can all alter whether a signature pattern registers from left to right or right to left. It will not be obvious at the time of data capture which way round a cast should be placed. Consequently, the program will have to look for comparisons in both orientations to establish all possible fits for a particular signature.

Initially the solution to the orientation problem would appear to be straightforward; reverse the sequence of figures in the light profile and reconduct the comparison. However, deeper consideration of this approach reveals a flaw. The approach would be reasonable if the profile being considered was an absolute record of the physical form of the mark. However, clearly the light profile is a record of the manner in which the surface responds to side lighting. Consequently, each ridge in a mark is represented by a peak, indicating the highlight at the top of the feature, followed by a trough that indicates the extent of the shadow that the ridge casts. The extent and depth of the shadow will reflect the height of the ridge and depend on the angle and position of the light. In other words a light profile is not an absolute record of ridge form. If the light profile was simply reversed the area of shadow would shift to the other side of the ridge highlight. The image produced would not be the same as turning the cast around because the lighting effect would no longer be from left to right (Fig.17.8)

Two approaches might be suggested as solutions to the above problem; one pre-emptive, one remedial. The pre-emptive method involves the capturing of two images for every cast looked at. The first image would have the cast in one orientation, the second in the opposite orientation. When the comparisons are conducted both images would be used and compared in the same manner as any other image. The remedial approach would involve a mathematical conversion that would effectively swap the peak and trough in the image independently and then turn the image round. At present it seems that the pre-emptive approach is the most

practical and reliable solution despite the increased storage space that this technique would imply.

17.5.2. Automated Correlation

At present the SigMatch program requires the user to select two images for comparison and then to request the machine to suggest the best fit. Future versions of the SigMatch program will need to automate this aspect of the procedure. The program will have to keep track of each comparison made and store the t -value result of each best fit.

In an automated comparison, the light profiles would be placed in their own area of the hard disk. The program would detect all the appropriate files and conduct the comparison test on each pair of light curves. The results of the comparison would be down loaded to a file which in essence would be a matrix that recorded the t -value result for each comparison (Fig.17.9).

17.5.3. Group Production

The SigMatch program has been written to experiment with methods of image matching. In its present form it does not attempt to establish relationships between each of the matched pairs. In other words the program does not yet possess any facility for generating groups of similar signatures. This activity is essential and its implementation will considerably enhance the possibilities of the computer approach.

To provide a grouping facility some form of cluster analysis would be required. As an example, a simple process might be envisaged that took the values of matches recorded in the correlation matrix as a basis for starting group formation. The highest values recorded in this matrix might be used as seeds for the core of each group; to each seed would be added the next highest value of match for each member of the correlated pair. New members would be admitted until the only values left in the matrix were those that were equal to or below the value chosen as designating a mismatch

17.6. Additional Potential

So far the discussion of the computerised approach has concentrated on the matching and grouping of similar signature forms. While this is intended as the principal use to which this technique might be put, additional potential uses can be proposed.

17.6.1. Simulating resharpener and detecting extra damage.

One aspect of tool signatures that is particularly hard to detect is resharpener. When matching is based only on visual comparison it is problematical to develop and apply well-defined rules for detecting the manner in which a signature will change with resharpener. Once a signature begins to be defined in terms of a set of figures it can be suggested that the way is open for the simulation of resharpener effects. In other words it is possible that the digitised form of a known signature could be adapted by a set of rules to simulate what that signature might look like after one or more resharpener episodes.

Some resharpener rules can be suggested. It is clear, for example, that there is a gradual diminishment of ridge height and width as the metal edge is eroded back. It is also apparent that the last features to disappear are the undulations at the top of the ridges as this is the last part of a gap to be removed.

The rate of resharpener is very difficult to determine and will to some extent depend on the ability and preferences of the user. Furthermore, different workers will sharpen more vigorously than others. However, if simulation proves to be a practical proposition, it could be suggested that a signature image could be slowly altered to see whether any additional matches were possible. In other words it is not strictly necessary to know the precise resharpener rate to explore the possible alterations of a signature.

One factor that may present some problems is the issue of additional damage. As an axe is used not only will it be sharpened it will also sustain extra damage. It would not be possible

simulate this process as it is essentially random. It may, however, be possible to use a form of template matching technique, which examines a signature for an underlying pattern. For example, additional damage is apparent between core groups WA and WD but underlying signature similarities are present.

17.6.2. Using additional information

It has been shown during this project that signatures are most effectively examined when other information is also considered. For the SigMatch program to be most effective it should eventually take into account other pieces of information. The program could, for example, record and apply the following:

- **Other facet features** - It has already been demonstrated in this thesis that the signature, on its own, tells only part of the story. Other facet features can help to confirm or deny links between marks. In particular the registration of side features provides useful guidance as to the absolute position of the signature on the blade edge. It should be a fairly simple task in future versions of the SigMatch program to allow the user to record the presence of side features. Once recorded this information could be used to limit the position at which comparisons were started or finished as a match would not be possible that overlapped a side feature. Consequently, comparison time would be cut down and clearer matches made.

The inclusion of jam curve features might also be recorded by the program. To take account of this information a section of code would have to be written that combined the matching of blade curves with the position of signature fit. This would involve the storage of a separate graph file containing the data relating to the curvature of the blade. A slightly different curve matching technique would also be needed to correlate the blade form details. Alternatively, a quicker approach would be to record the blade depth; the measurement used to produce the curvature index (fig.15.1). Using blade width and blade depth values would quickly identify tools with similar blade shapes.

- **Aspects of physical association** - When casts displaying different signatures occur on the same timber or on a physically associated timber the program could flag this situation; in this manner signature suites could be suggested and further relationships explored.
- **Dendrochronological information** - The program could also display and take into account dendrochronological information about the timber.
- **Spatial Distribution** - access to data relating to the position of particular piles and artifacts could allow for the program to produce plots giving the distribution of particular signature groups. The AutoSketch plotting program has been used in this project to produce plans of pile positions. It would not be too problematical to make the SigMatch program produce macro files that could be read by AutoSketch. Consequently, as groups were established by the program their distribution on site could be plotted.

The programming language used for the development of the SigMatch program allows for fairly easy access to the major database file formats. Consequently, data relating to factors such as timber position and dendrochronology could be accessed from existing databases. This would remove the necessity to re-enter data or to store such information along with the light profiles.

17.7. Conclusions.

The SigMatch program was written to illustrate the manner in which tool marks may be stored and matched with the aid of a computer. The program is still very much at the prototype stage; it has been written as an aid to the further investigation of this approach rather than as fully fledged signature matching tool. It is apparent, however, that there is considerable potential in a computerised matching procedure.

At its most basic the program demonstrates the manner in which signatures can be reduced to a single string of numbers. This process presents the opportunity to store signature information in an extremely cost effective fashion. Furthermore, the development of the

program has established a very efficient way of redisplaying this string of numbers as an image, as and when it is needed to be viewed. Consequently, there is no absolute requirement to keep the original image files on disk.

The SigMatch program has also demonstrated that images of signatures can be successfully matched by computer. The statistics chosen for this process appear successful. However, a series of further tests need to be conducted to establish the frequency and nature of possible errors. The program provides a platform by which these and other statistical methods can be assessed. It is a relatively simple task now that the mechanics of the program have been established to alter the code to experiment with different statistical methods.

The use of a computer to match marks is not intended to displace the human decision making process. The SigMatch program should eventually operate in unison with the approaches already advocated in this study. The role of the machine can be viewed as being to reduce some of the work load involved in the matching process. In particular it could be viewed as a tool that identifies marks that do not fit. By establishing which members of the data set do not match the number of comparisons that the human operator has to conduct could be considerably reduced.

CHAPTER 18

Summary

This final chapter briefly reviews the potential uses of tool marks and their signatures. This review is followed by a discussion of the manner in which tool mark examinations might be pursued at Oakbank and other sites in the future.

18.1. An overview of toolmark potential.

It was proposed in chapter 1 that axe marks can assist in the understanding of a number of aspects of a site's construction and general woodworking. These aspects can be summarised as follows:

Spatial and chronological aspects of construction.

- Indicating associations between otherwise unconnected timbers.
- Identifying structural patterns.
- Identifying building phases.
- Identifying associations with nearby sites or structures

Aspects of data verification and extension

- Providing independent checks on other techniques (e.g. Dendrochronology).
- Extending the information established for one timber to other timbers bearing the same signature.

Social aspects of construction

- Suggesting the number of axes/people involved in a particular structure.
- Suggesting workforce organisation.

Technological aspects of construction

- Reconstructing the functional types of tools within a tool kit.

Typological aspects of tool marks

- Fitting tool marks to known tool finds.

Of these aspects it is apparent from this study that the most clearly defined are the spatial and chronological aspects of construction. At this level signature matches and blade curve determinations can produce clear indications of associations between groups of timbers and start to reveal patterns of building on site. Of equal and related importance are the aspects of data verification and extension. The relationship between dendrochronology and signature associations is of particular importance. On sites, such as Oakbank, where dendrochronology relies on problematical species, signature links can provide a vital confirmation or rejection of weak links. This relationship can not only enhance the reliability of the chronologies produced it can also indicate aspects of the construction that might otherwise be missed.

The social aspects of construction are less easy to define. These aspects inevitably involve a degree of assumption. In particular two factors make precise determination of these issues difficult:

- The relationship between the order of production and the order of driving is difficult to determine. It is highly unlikely that piles will be pointed just before driving. It is far more probable that driving follows on from a phase during which most of the trees required for construction are felled and pointed. Consequently, the distribution of particular signatures on the site will reflect the order in which the timbers were drawn from the collection of pre pointed timbers, rather than directly indicating the order in which the timbers were pointed
- There is no certain correlation between the number of axes identified and the number of people involved. However, while this is the case the number of tools reconstructed within a single, clear phase of building will give an impression of the size of the workforce that would otherwise be difficult to establish.

Comments on the technological aspects of tool mark examination predominate in the archaeological literature on worked timbers. The identification of certain functional classes of

tools used on a site is clearly achievable, given a sufficient number and quality of marks. In some cases such marks can suggest tool forms that are not expected. The hole boring tool that appears to have been used at Oakbank is a case in point (section 7.2.4). The tool that produced these marks does not seem to be clearly represented amongst the group of known tools from the period.

Pursuit of typological aspect of the toolmarks found at Oakbank Crannog has revealed some interesting possibilities. Because of the imprecise dates for the site construction it is difficult to draw firm conclusions from this examination although the implication, at present, is that iron socketed axes were used for at least some of the timbers. What is clear from the study is that with aid of signature combination many of the axes used on the site will be fully defined in terms of blade width and shape. Such an assemblage of forms from a site will provide an important data set reflecting the actual tools used during a particular period. Future studies on crannogs and other sites, particularly those that are well dated, producing similar assemblages may indicate the extent to which known tool finds actually represent the dimensions of the tools used in everyday operations. Such comparisons may consequently lead into issues such as the interpretation of hoards or the nature of stray finds.

The information from well-dated sites may in turn be used to assess less well dated sites. It is possible, for example, that the combination of edge curvature and width distributions in a particular assemblage will be indicative of certain period. Certainly, because such assemblages reflect actual woodworking operations, they may be regarded as more appropriate comparative data than known tool find assemblages.

18.2. Future analysis at Oakbank and Other sites.

A key quality of signature examination is the potential for some of the analysis to be conducted on site in parallel with the excavation season. Apart from the moulding materials there is no absolute requirement for any extra equipment, although a computer with a database and spreadsheet program is highly desirable.

As a project progresses an increasing number of well-established groups will be identified. In some cases the groups can become so familiar to those casting the timbers that a member of a group may even be noticed underwater. It has been found convenient to glue together representatives of each of the established core groups. Previously established groups can therefore be quickly compared with freshly taken casts. This will cut down comparison time during post excavation and enable decisions about sampling or raising timbers to be made on-site during the same season. The on-site examination process will pick up most of the obvious connections; the finer interpretation and the establishment of new groups can await analysis in the laboratory.

If the computerised approach proves to have a practical application, and financial considerations allow, the on site visual comparison with known cast groups could be supplemented or replaced by a video capture system. A situation could be envisaged in which the site office contained a video attached to a portable computer. Newly acquired casts could be immediately digitised by the video and compared with the database of previous cast images (or rather their Light Profiles). The time taken to compare the small number of new casts produced each day could be fairly rapid, giving the archaeologist an immediate idea of which timbers are associated.

In either of the above cases the ability to conduct on site analysis will also prove useful when looking for possible inter-site connections. If, for example, the crannog near to Oakbank were excavated inter-site connections might be considered given their similar radiocarbon dates. To facilitate this examination the principal signature groups, or suites of groups, associated with phases in the construction of Oakbank, could also be made available in the site office or on a database. This would enable the early recognition of a connection between the sites; perhaps more importantly it might signal when certain phases involve active interaction.

18.3. Closing remarks.

On archaeological sites with excellent timberwork surviving the recording and utilisation of signature information needs to be carefully considered. It is hoped that the current work has demonstrated the various areas of site interpretation that can benefit from the examination of this type of information; above all this data provides an independent tool for establishing precise temporal associations between artifacts. These associations can potentially be established very quickly, on site, in parallel with excavation. Furthermore, the equipment required to conduct this analysis need not be prohibitively expensive.

While the basic recording and matching of signatures can be conducted both simply and cheaply it is felt that utilisation of image analysis may, in the future, considerably enhance the efficiency with which signatures are used.

APPENDIX A

Calibration results for the Oakbank Crannog radiocarbon dates

UNIVERSITY OF WASHINGTON
QUATERNARY ISOTOPE LAB
RADIOCARBON CALIBRATION PROGRAM REV. 3.0
Stuiver, M. and Reimer, P.J., 1993, Radiocarbon, 35, p. 215-230.

Calibration file(s): INTCAL93.14C
Listing file: OAK2.TXT

GU-1325 OB1

Oak Pile - Loch bed close to the extension feature

Radiocarbon Age BP **2410 ± 60**
Calibrated age(s) cal **BC 410**

cal AD/BC age ranges obtained from intercepts (Method A):
one Sigma** cal BC 753 - 696 533 - 397
two Sigma** cal BC 769 - 380

Summary of above:

minimum of cal age ranges (cal ages) maximum of cal age ranges:
1s cal BC 753 (410) 397
2s cal BC 769 (410) 380

cal AD/BC age ranges (cal ages as above) from probability distribution (Method B):

% area enclosed	cal BC age ranges		relative area under probability distribution
68.3 (1s)	cal BC	750 - 700	.23
		530 - 400	.77
95.4 (2s)	cal BC	760 - 620	.32
		600 - 390	.68

GU-1323 OB2

Oak Pile
Acc No. 103

Radiocarbon Age BP **2545 ± 55**
Calibrated age(s) cal **BC 770**

cal AD/BC age ranges obtained from intercepts (Method A):
one Sigma** cal BC 797 - 757 680 - 546
two Sigma** cal BC 809 - 484 446 - 422

Summary of above:

minimum of cal age ranges (cal ages) maximum of cal age ranges:
1s cal BC 797 (770) 546
2s cal BC 809 (770) 422

cal AD/BC age ranges (cal ages as above)
from probability distribution (Method B):

% area enclosed		cal BC age ranges	relative area under probability distribution
68.3 (1s)	cal BC	800 - 760	.27
		680 - 550	.73
95.4 (2s)	cal BC	810 - 490	.98
		440 - 420	.02

Small Alder stake point from top of site

Radiocarbon Age BP 2360 ± 60

Calibrated age(s) cal BC 400

cal AD/BC age ranges obtained from intercepts (Method A):

one Sigma** cal BC 413 - 384

two Sigma** cal BC 756 - 684 540 - 360 283-255

Summary of above:

minimum of cal age ranges (cal ages) maximum of cal age ranges:

1s cal BC 413 (400) 384

2s cal BC 756 (400) 255

cal AD/BC age ranges (cal ages as above)
from probability distribution (Method B):

% area enclosed	cal BC age ranges		relative area under probability distribution
68.3 (1s)	cal BC	750 - 730	.06
		530 - 370	.94
95.4 (2s)	cal BC	760 - 630	.17
		560 - 350	.73
		310 - 210	.10

Small Alder stake point from top of site

Radiocarbon Age BP **2405 ± 60**
Calibrated age(s) cal **BC 410**

cal AD/BC age ranges obtained from intercepts (Method A):
one Sigma** cal BC 751 - 705 529 - 396
two Sigma** cal BC 767 - 378

Summary of above:

minimum of cal age ranges (cal ages) maximum of cal age ranges:
1s cal BC 751 (410) 396
2s cal BC 767 (410) 378

**cal AD/BC age ranges (cal ages as above)
from probability distribution (Method B):**

% area enclosed	cal BC age ranges		relative area under probability distribution
68.3 (1s)	cal BC	750 - 700	.22
		530 - 400	.78
95.4 (2s)	cal BC	760 - 620	.31
		600 - 380	.69

GU-3468 OB5

Causeway Pile
Acc. No. C18

Radiocarbon Age BP 2490 ± 50

Calibrated age(s) cal BC 758, 679, 650, 547

cal AD/BC age ranges obtained from intercepts (Method A):

one Sigma** cal BC 772 - 511 436 - 427

two Sigma** cal BC 795 - 404

Summary of above:

minimum of cal age ranges (cal ages) maximum of cal age ranges:

1s cal BC 772 (758, 679, 650, 547) 427

2s cal BC 795 (758, 679, 650, 547) 404

cal AD/BC age ranges (cal ages as above)
from probability distribution (Method B):

% area enclosed	cal BC age ranges		relative area under probability distribution
68.3 (1s)	cal BC	765 - 751	.07
		735 - 611	.56
		609 - 527	.38
95.4 (2s)	cal BC	781 - 473	.91
		464 - 417	.09

GU-3469 OB6

Deep Alder Pile
Acc. No.1744

Radiocarbon Age BP 2560 ± 50
Calibrated age(s) cal BC 785

cal AD/BC age ranges obtained from intercepts (Method A):
one Sigma** cal BC 799 - 762 620 - 600
two Sigma** cal BC 810 - 524

Summary of above:

minimum of cal age ranges (cal ages) maximum of cal age ranges:
1s cal BC 799 (785) 600
2s cal BC 810 (785) 524

cal AD/BC age ranges (cal ages as above)
from probability distribution (Method B):

% area enclosed		cal BC age ranges	relative area under probability distribution
68.3 (1s)	cal BC	802 - 759	.38
		676 - 658	.10
		640 - 551	.52
95.4 (2s)	cal BC	813 - 520	1.00

GU-3470 OB7

Deep Oak Pile

Acc. No. 1780

Radiocarbon Age BP 2510 ± 50

Calibrated age(s) cal BC 763, 620, 601

cal AD/BC age ranges obtained from intercepts (Method A):

one Sigma** cal BC 785 - 525

two Sigma** cal BC 799 - 408

Summary of above:

minimum of cal age ranges (cal ages) maximum of cal age ranges:

1s cal BC 785 (763, 620, 601) 525

2s cal BC 799 (763, 620, 601) 408

**cal AD/BC age ranges (cal ages as above)
from probability distribution (Method B):**

% area enclosed	cal BC age ranges		relative area under probability distribution
68.3 (1s)	cal BC	780 - 752	.13
		703 - 531	.87
95.4 (2s)	cal BC	795 - 479	.96
		451 - 420	.04

GU-3471 OB8

Off-site Alder Pile

Acc. No. 1748 (First of two samples)

Radiocarbon Age BP **2490 ± 50**

Calibrated age(s) cal **BC 758, 679, 650, 547**

cal AD/BC age ranges obtained from intercepts (Method A):

one Sigma** cal BC 772 - 511 436 - 427

two Sigma** cal BC 795 - 404

Summary of above:

minimum of cal age ranges (cal ages) maximum of cal age ranges:

1s cal BC 772 (758, 679, 650, 547) 427

2s cal BC 795 (758, 679, 650, 547) 404

**cal AD/BC age ranges (cal ages as above)
from probability distribution (Method B):**

% area enclosed	cal BC age ranges		relative area under probability distribution
68.3 (1s)	cal BC	765 - 751	.07
		735 - 611	.56
		609 - 527	.38
95.4 (2s)	cal BC	781 - 473	.91
		464 - 417	.09

GU-3472 OB9

Off site Alder Pile

Acc. No. 1748 (2nd of Two samples)

Radiocarbon Age BP 2450 ± 50

Calibrated age(s) cal BC 519

cal AD/BC age ranges obtained from intercepts (Method A):

one Sigma**	cal BC	760 - 671	667 - 630
		593 - 581	561 - 407
two Sigma**	cal BC	780 - 397	

Summary of above:

minimum of cal age ranges (cal ages) maximum of cal age ranges:

1s cal BC 760 (519) 407

2s cal BC 780 (519) 397

**cal AD/BC age ranges (cal ages as above)
from probability distribution (Method B):**

% area enclosed	cal BC age ranges		relative area under probability distribution
68.3 (1s)	cal BC	758 - 679	.36
		547 - 409	.63
95.4 (2s)	cal BC	764 - 617	.41
		604 - 404	.59

References for datasets used:

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APPENDIX B

Signature Core Group - Timber Details

Notes:

The following appendix gives the timber details for each of the signature core groups.

The cast no. in each of the following table entries refers to the actual cast used in figures 10.1 - 10.31. The casts are stored as part of the site archive.

Raised timbers are indicated by the site code; OB indicates that the timber is still in-situ, OB88 indicates that the timber was removed from the site in 1988.

The co-ordinates are relative to control point A1, which is at position 0,0. The Y co-ordinates increase from A1 - E1 while the X co-ordinates increase from A1 - A8 (see fig.5.2).

Features:

EXT - Extension Feature

OS - Off-Site Post Alignment

F4 - Large pile (379) flanked by three smaller uprights on south, southwest and west. Possibly east 'doorpost' structure (Dixon,1984)

F6 - Feature defined as possibly being part of the outer wall and/or inner walkway supports (Dixon,1984)

Timber No.	Cast No.	Group	Type	Area	Feature	Site	Length (cm)	Diameter (cm)	X Co-ordinate (m)	Y Co-ordinate (m)
1014	01	A	Pile	A6	EXT	OB		10	28.70	4.69
1015	01	A	Pile	A6	EXT	OB		17	29.07	4.50
1019	01	A	Pile	B6	EXT	OB		9	29.92	5.38
1035	13	A	Pile	B7	EXT	OB90	96	15	33.18	9.75
1047	01	A	Pile	C7	EXT	OB88	57	13	31.80	14.05
1050	14	A	Pile	C7	EXT	OB88	160	14	31.48	14.60
1052	01	A	Pile	D7	EXT	OB		13	30.02	15.01
1054	01	A	Pile	D6	EXT	OB		14	28.18	15.65
X12A	01	A	Pile	B7	EXT	OB		10	30.13	5.72
-X12	02	B	Pile	B7	EXT	OB		13	30.00	5.70
1000	01	B	Pile	B6	EXT	OB		17	24.85	5.10
1001	01	B	Pile	B6	EXT	OB		20	25.46	5.13
1012	01	B	Pile	B6	EXT	OB		15	28.15	4.93
1013	01	B	Pile	A6	EXT	OB		10	28.53	4.83
1016	01	B	Pile	B6	EXT	OB		13	29.03	5.25
1017	01	B	Pile	B6	EXT	OB		13	29.38	5.45
1023	01	B	Pile	B7	EXT	OB		13	30.50	6.03
1025	01	B	Pile	B7	EXT	OB		13	31.38	7.35
1026	01	C	Pile	B7	EXT	OB		14	32.00	6.68
1028	01	C	Pile	B7	EXT	OB		10	32.23	7.25
1038	01	C	Pile	C7	EXT	OB		18	33.15	11.00
1039	01	C	Pile	C7	EXT	OB		21	34.05	11.23
1040	01	C	Pile	C7	EXT	OB		15	32.88	11.65
1051	11	C	Pile	C7	EXT	OB88	141	12	30.98	14.80

Timber No.	Cast No.	Group	Type	Area	Feature	Site	Length	Diameter (cm)	X Co-ordinate (m)	Y Co-ordinate (m)
1045	02	D	Pile	C7	EXT	OB88	80	15	32.98	13.95
T1	01	D	Pile	B7	EXT	OB		15	34.23	8.27
1027	01	E	Pile	B7	EXT	OB		15	33.00	6.13
1037	01	E	Pile	C7	EXT	OB		14	34.34	10.53
1004	02	F	Pile	B6	EXT	OB		13	26.58	6.28
1005	02	F	Pile	B6	EXT	OB		15	26.78	6.35
1035	14	G	Pile	B7	EXT	OB90	96	14	33.18	9.75
1050	13	G	Pile	C7	EXT	OB88	160	14	31.48	14.60
1051	10	G	Pile	C7	EXT	OB88	141	12	30.98	14.80
1053	01	G	Pile	D6	EXT	OB		18	29.45	15.25
1056	01	G	Pile	D6	EXT	OB		13	27.43	15.18
1058	01	G	Pile	C6	EXT	OB		13	25.88	14.73
1008	01	H	Pile	B6	EXT	OB		18	28.33	6.24
1021	01	H	Pile	B7	EXT	OB		30	29.95	6.93
1006	01	I	Pile	B6	EXT	OB		24	27.15	6.88
1007	01	I	Pile	B6	EXT	OB		14	27.64	6.43
1010	01	I	Pile	B6	EXT	OB		15	28.78	6.19
1055	01	I	Pile	D6	EXT	OB		14	27.88	15.08
1003	01	J	Pile	B6	EXT	OB		15	26.28	6.26
T4	01	J	Pile	B7	EXT	OB		15	30.18	6.76
1030	01	K	Pile	B7	EXT	OB		16	33.75	7.58
1034	01	K	Pile	B7	EXT	OB		13	34.58	9.25
T2	01	K	Pile	B7	EXT	OB		15	34.50	9.78

Timber No.	Cast No.	Group	Type	Area	Feature	Site	Length	Diameter (cm)	X Co-ordinate (m)	Y Co-ordinate (m)
1044	01	L	Pile	C7	EXT	OB		14	33.78	13.15
1049	01	L	Pile	C7	EXT	OB88	85	14	32.55	14.75
1036	03	M	Pile	C7	EXT	OB93	110	15	33.23	10.45
1042	01	M	Pile	C7	EXT	OB		13	32.66	12.22
1043	01	M	Pile	C7	EXT	OB		16	32.68	12.75
1051	06	M	Pile	C7	EXT	OB88	141	12	30.98	14.80
1060	01	N	Pile	C6		OB			25.00	13.50
1744	01	N	Pile			OB				
1582	01	0	Pile	C1	-	OB91	144	17	-	-
1748	01	P	Pile	'C7	OS	OB92	63	10	31.17	-12.61
1749	01	P	Pile	'C7	OS	OB		10	32.88	-12.59
1752	01	P	Pile	'C6	OS	OB		12	29.28	-12.78
1748	02	Q	Pile	'C7	OS	OB92	63	10	31.17	-12.61
1758	01	Q	Pile	'C4	OS			10	15.39	-12.88
1748	03	R	Pile	'C7	OS	OB92	63	10	31.17	-12.61
1751	01	R	Pile	'C8	OS	OB		10	37.09	-12.85
1754	01	R	Pile	'C6	OS	OB		11	25.14	-13.56
1756	01	R	Pile	'C4	OS			10	19.38	-13.13
0495	01	S	Pile	A3	F6		72.5	15	13.78	4.21
0505	04	S	Pile	A3	F6		60	15	14.50	4.20
0710	01	S	Pile	A4		OB		18	15.83	3.85

Timber No.	Cast No.	Group	Type	Area	Feature	Site	Length	Diameter (cm)	X Co-ordinate (m)	Y Co-ordinate (m)
1032	01	T	Pile	B7	EXT	OB		14	32.68	8.68
1036	01	T	Pile	C7	EXT	OB93	110	15	33.23	10.45
1059	02	T	Pile	C6	EXT	OB		12	25.38	14.31
0379	01	U	Pile	B3	F4	OB		18	12.00	5.27
0422	01	U	Pile	B3	F6	OB		16	13.14	5.30
0421	01	V	Pile	B3		OB		9	13.07	5.70
0704	01	V	Pile	A4		OB		13	15.43	4.16
1018	05	W	Pile	A6	EXT	OB90	89	14	29.40	4.60
1652	01	WD	Pile	C1		OB		12	1.01	11.73
1035	01	X	Pile	B7	EXT	OB90	96	14	33.18	9.75
1046	02	X	Pile	C7	EXT	OB88	114	15	31.92	13.60

Timber No.	Cast No.	Group	Type	Area	Context	Site	Length (cm)	Width (cm)	Thickness (cm)
5014	01	WA	Woodchip	A2	0009	OB90	6.00	5.10	0.50
5047	01	WA	Woodchip	A2	0007	OB90	11.00	9.20	2.40
5070	01	WA	Woodchip	A2	0012	OB90	22.00	11.20	5.70
5022	01	WB	Woodchip	A2	0009	OB90	7.15	3.90	1.21
5032	01	WB	Woodchip	A2	0009	OB90	7.95	3.35	1.11
5008	01	WC	Woodchip	A2	0007	OB90	8.82	4.85	1.51
5011	01	WC	Woodchip	A2	0007	OB90	6.71	5.23	1.20
5002	01	WD	Woodchip	A2	0007	OB90	13.00	9.50	4.50
5005	01	WD	Woodchip	A2	0006	OB90	5.30	1.70	0.60
5042	01	WD	Woodchip	A2	0009	OB90	9.30	4.91	2.80
5016	01	WE	Woodchip	A2	0009	OB90	7.80	7.15	2.40
5051	01	WE	Woodchip	A2	0009	OB90	8.30	5.20	1.30
5083	01	WF	Woodchip	B2	4a	OB88	8.90	5.50	1.50
5117	01	WF	Woodchip	B2	4/4a	OB88	4.00	4.50	0.40
5118	01	WF	Woodchip	B2	4/4a	OB88	3.40	3.20	1.70
5122	01	WF	Woodchip	B2	4a	OB88	5.60	5.00	1.50
5006	01	WG	Woodchip	A2	0007	OB90	6.70	4.20	1.50
5055	01	WG	Woodchip	A2	0009	OB90	17.00	7.00	0.50
5027	01	WH	Woodchip	A2	0009	OB90	16.00	11.50	3.90
5163	01	WI	Woodchip	B2	4/4a	OB88	12.00	10.50	4.00

APPENDIX C

The experimental work

Experimental work conducted during this research provided useful experience and a general background to a number of comments made throughout the thesis. However, it was felt that it would be extremely problematical to establish experiments, with the necessary forms of control, to reliably quantify rates of wear and damage. There are a considerable number of variables to consider when setting up such an experiment. Blade edge hardness, for example, varies from one axe to another and consequently different axes would probably wear, or need resharpening, at different rates. Expertise and fitness will also have a bearing on the rate of resharpening. An unfit or inexperienced person can considerably increase the number of blows required to produce a particular object and also the amount of damage that occurs to a tool. Personal preference will also be a consideration; it is clear that some people prefer to maintain a keener edge than others. The form of the surrounding ground may also effect the amount of damage that occurs to an axe and consequently the number of times it might require resharpening.

In addition to the possible procedural problems to setting up a reliable experimental method it was felt that in time the site itself might provide answers to these questions. It should be possible to start estimating the length of time over which a signature can survive by observing the maximum number of timbers that bear exactly the same pattern.

As mentioned above experimentation was used to inform the thesis in a general fashion, providing the author with a feeling for the use a variety of tools. In addition to small modern axes, two bronze axes were used. The first of these was a flanged axe, based on a find from Killin, Loch Tay, Perthshire, that had been made during the undergraduate study (Sands,1989; Schmidt & Burgess,1981,Plate 43,No.549). This axe was produced at the Slade School of Art, University College London, under the guidance of their technician Terry Jones. The two piece mould was made with compacted casting sand and the bronze contained approximately 8% tin. The second axe was based on a socketed form from a hoard found in Monmore Killin (Schmidt & Burgess, 1981, plate 82, No.1216). This axe was produced at the Edinburgh School of Art using a lost wax method with an 8% tin bronze. Both of the axes had their edges heated and hammer hardened.

APPENDIX D

Technical Notes

Notes on the programming language

The programming language used to produce the SigMatch program was Microsoft's Visual Basic v.3.0 Professional Edition. The programming language is based on visual design principles where the user develops the look of the interface interactively. The coding is event driven and each block of code is attached to a screen object or user driven event such as mouse movement or key press.

Notes on the statistics used in the SigMatch program

The matching statistics currently used in the SigMatch program are those that are commonly used in dendrochronology:

$$r = \pm \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \quad (\text{Walsh, 1990, 244-248; Schweingruber, 1989, 84})$$

where:

r = Correlation coefficient

x = the sequence of pixel values in the upper image that overlap the lower image.

y = the sequence of pixel values in the lower image that overlap the upper image.

followed by:

$$t = r \sqrt{\frac{N-2}{1-r^2}} \quad (\text{Walsh, 1990, 253; Schweingruber, 1989, 84})$$

where:

N = number of pixels that overlap between the two images.

The higher the value of t the better the match between the two images. When the program is choosing the best position of fit a loop is used which calculates the r and then the t - score for each position of overlap between the two images. The scores are stored in an array which is then searched for the highest value. The position of the value in the array indicates to the program where the lower image should be placed against the upper to demonstrate the fit.

Glossary

Association sequence - a sequence of casts that demonstrate most clearly the associations between **core groups**.

Blade edge - the cutting edge of a tool.

Blade sides - the extreme ends of a blade edge.

Blocks - A term used by Dr. Crone to describe groups of timbers that have been associated by dendrochronology using visual matching techniques. These represent the groups of timbers whose ring patterns show the best visual similarity.

Core Group - the basic building blocks of signature matches. Core groups represent perfect or near perfect associations between signatures on different casts.

Core Group Amalgamation - demonstrating that apparently different core groups contain members of a single **Signature set**, in other words different core groups are shown to be the product of the same axe.

Core Group Sequence - a collection of cast facets which when placed in a particular sequence reflect the life of the tool both in-terms of resharpening and extra damage incurred. This will be built up from consideration of a series of **Association sequences** and is a bi-product of the arguments that lead to **Core Group Amalgamation**.

dpi - Dots-per-inch - a measurement of resolution. It represents the number of points of information that are recorded or printed per inch.

Entry Heel - A feature at the top of a facet representing the point of entry of the axe. It appears as shift in angle when the facet is looked at in cross section.

Facet Junctions - A term coined by O'Sullivan to describe the connection between one facet and the next (O'Sullivan,1991,61).

Grey Scale - A scale which represents the different shades of grey that are represented in an image. If a digitised image is stored with each pixel represented by a single byte then the number of different shades of grey that can be recorded is 256 (the highest number of combinations that can be represented by an eight digit binary value i.e. a byte). A 0 value represents black while a figure of 255 represents white. Values in between represent a progression of grey shades from black to white.

Jam Curve - A term coined by O'Sullivan (1991,61-62) to describe the accurate blade edge impression left after an unsuccessful axe strike. After such a strike the axe is left jammed into the wood surface and has to be pulled back out. This leaves a small area of jagged wood, underneath this flap of wood is the jam curve.

Light Profile - A graph representing the average **Grey Scale** values across an image.

Pixel - the smallest resolvable point on a digitised image.

Side features - these are small areas of upstanding wood to the left or right of a facet. They represent a registration of the **blade sides** of an axe. Side 1 represents a registration to the left of the facet when the strike direction runs from top to bottom as the facet is looked at from the front. Side 2 is registration to the right.

Signature Combination Technique - A technique by which features on different facets may be linked together through common signature elements.

Signature Set - a single axe has the potential during its life time to produce many different signatures as it is sharpened and redamaged. The signature set of an axe contains all these signatures. Not all the members of a signature set will be present on a site but there may be enough to form a **Core Group Sequence**.

Sort.String Chronology - A floating chronology produced by Dr. Crone for a sample of timbers from Oakbank Crannog. The chronology is based on a computer assisted grouping processes developed by Dr. Crone and gives a slightly different picture than that shown in the **Traditional Chronology**.

Traditional Chronology - A floating chronology produced by Dr. Crone for a sample of timbers from Oakbank crannog. It is based on the visual matching of the average curves produced from each **block** of associated timbers.

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BAR.I.S - British Archaeological Reports - International Series.
IJNA - International Journal of Nautical Archaeology.
JFA - Journal of Field Archaeology.
JAS - Journal of Archaeological Science.
OJA - Oxford Journal of Archaeology
PPS - Proceedings of the Prehistoric Society.
PSAS - Proceedings of the Society of Antiquaries of Scotland
SELRC - Severn Estuary Levels Research Committee.
SLP - Somerset Levels Papers.
STUA - Scottish Trust for Underwater Archaeology.
TGAS - Transactions of Glasgow Archaeological Society.
UJA - Ulster Journal of Archaeology
WARP - Wetland Archaeological Research Project.

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